BARRO COLORADO ISLAND

100 YEARS

Smithsonian
Tropical Research Institute

GAMBOA RAINFOREST RESERVE

June | Junio 18 – 20, 2024

GORDON AND BETTY MOORE FOUNDATION

SENACYT
Secretaría Nacional de Ciencia, Tecnología e Innovación

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June | Junio 18, 2024

Time	*Hora*	Room	*Salón*
	Gamboa Grand Ballroom	Camino de Cruces
8:30 - 10:00	Opening Plenary *Sesión Plenaria de Apertura*	
10:00 - 10:30	Coffee Break	*Descanso*	
10:30 - 12:00	Insights into the fundamental biology and global change responses of tropical forests from very long-term studies. *Lecciones de biología fundamental y respuestas al cambio global a partir de estudios a muy largo plazo.*	
12:00 - 13:30	Lunch	*Almuerzo - Corotu Restaurant and Los Guayacanes*	
13:30 - 15:00	The long-term research legacy. *El legado de la investigación a largo plazo.*	Discussion Panel: The Educational Legacy of BCI and STRI: 100 Years and Beyond. *Panel de discusión: El legado educativo de BCI y STRI: 100 años y más allá.*
15:00 - 16:00	Poster session *Sesión de posters*	
16:00 - 17:20	Long-term research and historical studies. *Investigaciones a largo plazo y estudios históricos.*	Discussion Panel: The great and largely overlooked value of long-term field stations for conservation. *Panel de discusión: El gran valor de las estaciones de campo a largo plazo para la conservación.*
17:20 - 17:30	Closing words *Palabras de cierre*	

8:30 - 10:00 | Gamboa Grand Ballroom
Opening Plenary
Sesión Plenaria de Apertura

8:30 Opening words | ***Palabras de bienvenida.*** Josh TEWKSBURY, Ira Rubinoff Director, Smithsonian Tropical Research Institute

9:00 **Keynote: The ecology, evolution and conservation potential of anti-herbivore defenses in rainforest trees.** Phyllis COLEY, Distinguished Professor Emerita of Biology at the University of Utah, and member of the National Academy of Sciences of the USA.

10:00 Coffee Break | *Descanso*

10:30 - 12:00 | Gamboa Grand Ballroom
Insights into the fundamental biology and global change responses of tropical forests from very long-term studies.
Lecciones de biología fundamental y respuestas al cambio global a partir de estudios a muy largo plazo.

10:30 **A century of bird studies on Barro Colorado Island.** W. Douglas ROBINSON

10:45 **How Tropical Forest Trees Regenerate: Insights from Long-Term Studies of Flower and Seed Production and Seedling Dynamics.** S. Joseph WRIGHT

11:00 **Insights from the understory: Long-term monitoring of seedlings in the Barro Colorado Island 50-ha Forest Dynamics Plot.** Liza S. COMITA

11:15 **Insights into tropical forest nutrient limitation from a factorial nitrogen, phosphorus, and potassium addition experiment in an old-growth forest.** Joseph B. YAVITT

11:30 **Long-term monitoring on Barro Colorado Island suggests the value of small conservation preserves for tropical insects.** Greg LAMARRE

11:45 **Panamabiota.org: An ever-growing resource of information on Panamanian species.** Edward E. GILBERT

11:55 **The Smithsonian Tropical Data Portal – Helping people preserve, share, and discover tropical data and knowledge.** Helene C. MULLER-LANDAU

12:00 Lunch | *Almuerzo*

13:30 - 15:00 | Camino de Cruces
Discussion Panel: The Educational Legacy of BCI and STRI: 100 Years and Beyond.
Panel de discusión: El legado educativo de BCI y STRI: 100 años y más allá.
Organized by | *Organizado por:* Omar López, Secretario Técnico, SENACYT (Sistema Nacional de Investigación de Panamá)
Panelists | *Panelistas:*
- Owen MCMILLAN
- Omar LÓPEZ
- Carlos JARAMILLO
- Sabrina AMADOR

13:30 - 15:00 | Gamboa Grand Ballroom
The long-term research legacy.
El legado de la investigación a largo plazo.

13:30 **Biogeographic assembly of BCI's tree community — Insights from widespread tree species.** Chris DICK

13:45 **The Limbo long-term bird project: Lessons from the past 47 years and future directions.** Kimberley C. JORDAN

14:00 **Seed-fungal interactions: Lessons from BCI research and a few perspectives.** Paul-Camilo ZALAMEA

14:15 **Increasing liana abundance in tropical forests: Patterns, causes, & consequences.** Stefan A. SCHNITZER

14:30 **The past, present and future of bat research on Barro Colorado Island, and beyond.** Rachel PAGE

14:45 **BCI and the ever-expanding legacy of Stan Rand.** Michael J RYAN

15:00 Coffee break | *Descanso*

15:00 - 16:00 | Gamboa Grand Ballroom
Poster session
Sesión de posters

P1 **Barro Colorado Island long-term environmental monitoring program.** Steven PATON

P2 **Lutz Creek and Conrad Trail Stream hydrology, Barro Colorado Island; Two leaky catchments.** Robert F. STALLARD

P3 **Soils of Barro Colorado Island.** Joseph B. YAVITT

16:00 - 17:20 | Camino de Cruces
Discussion Panel: The great and largely overlooked value of long-term field stations for conservation.
Panel de discusión: El gran valor de las estaciones de campo a largo plazo para la conservación.
Organized by | Organizado por: Russell A. Mittermeier, Re:wild Chief Conservation Officer and Chair, IUCN SSC Primate Specialist Group
Panelists | *Panelistas:*
- Patricia C. WRIGHT
- Karen B. STRIER
- Fanny M. CORNEJO
- Sofia RODRIGUEZ
- Oris SANJUR

16:00 - 17:30 | Gamboa Grand Ballroom
Long-term research and historical studies.
Investigaciones a largo plazo y estudios históricos.

16:00 **Vegetation of BCI during the Last Glacial Maximum.** Carlos JARAMILLO

16:10 **Four centuries of human presence before the forests: Barro Colorado and the Transisthmian zone in the Early Modern Period.** Tomás MENDIZÁBAL

16:20 **The landscape history of Barro Colorado and Gamboa: Remembering the old towns of Gorgona and Cruces.** Marixa LASSO

16:30 **Herbivory constrains symbiotic nitrogen-fixing trees via density-dependent effects.** Sarah A. BATTERMAN

16:40 **Barro Colorado Island: is flora and its role in the study of Araceae.** Thomas CROAT

16:50 **100 years of discoveries in termite science on and around BCI, and more to come.** Yves ROISIN

17:00 **Green iguanas and the recognition of reptile sociality.** Gordon M. BURGHARDT

17:10 **Questions and answers period** | ***Período de preguntas y respuestas***

17:20 **Closing words on the legacy of BCI.** Oris SANJUR

10:30 | Gamboa Grand Ballroom
Organized oral session: Insights into the basic biology and global change responses of tropical forests from very long-term studies.
Ecological patterns and processes vary substantially among years due to interannual variation in climate and anthropogenic influences, as well as stochastic internal dynamics. Very long-term studies that maintain consistent observations and/or experimental treatments over decades thus provide uniquely valuable insights into basic biology. They are also critical to disentangling the effects of ongoing global anthropogenic change from other sources of interannual variation. Thanks to the long-term support of the Smithsonian Tropical Research Institute, Barro Colorado Island and Central Panama more generally host a disproportionate number of important, very long-term studies in tropical forests. This session highlights some of these key studies and how they have contributed to our understanding of tropical forests.

13:30 | Camino de Cruces
Discussion Panel: The Educational Legacy of BCI and STRI: 100 Years and Beyond
Organized by Omar López, Secretario Técnico, SENACYT (Sistema Nacional de Investigación de Panamá)
The Barro Colorado Island field station, and the Smithsonian Tropical Research Institute more generally, have long played an important role in training and educating tropical scientists. This currently includes a robust Fellowship and Internship program; a long-running field course for Panamanian students; a graduate training partnership with McGill University; symposia, training courses, and professional development workshops for the STRI academic community; and field courses for international universities.

In this session, panelists will first present a historical overview of STRI's academic programs, highlighting changes in funding and demographics of Interns and Fellows over the last ten years. This overview will provide the foundation for subsequent group discussion about how STRI can build from this legacy to better train the next generation of tropical scientists and tropical science leaders. Discussions will be conducted in small breakout groups to encourage participation, with the overarching goal of obtaining input from the broader community that can be used to develop the future vision of STRI's academic programs.

Panelists
- Owen MCMILLAN, Academic Dean, STRI
- Omar LÓPEZ, Secretary, SENACYT (Sistema Nacional de Investigación de Panamá)
- Carlos JARAMILLO, Staff scientist, STRI
- Sabrina AMADOR, Staff scientist, STRI

16:00 | Camino de Cruces
Discussion Panel: The great and largely overlooked value of long-term field stations for conservation
Organized by Russell A. Mittermeier, Re:wild Chief Conservation Officer and Chair, IUCN SSC Primate Specialist Group
Long-term field research stations in the tropics are often seen as being mainly focused on research. However, it is clear that these stations also have deep and far-reaching conservation value. The panelists discuss their experiences based on their leadership roles at major research stations and highlight the many contributions that these stations make to biodiversity knowledge and conservation in general.

Panelists
- Patricia C. WRIGHT, Stony Brook University, Centre ValBio Research Station, Madagascar
- Karen B. STRIER, Vilas Research Professor & Irven DeVore Professor, Department of Anthropology, University of Wisconsin-Madison
- Fanny M. CORNEJO, Executive Director, Yunkawasi
- Sofia RODRIGUEZ, Director of Academics, Organization for Tropical Studies
- Oris SANJUR, Deputy Director, Smithsonian Tropical Research Institute

The discussion panel will begin with the following talks:

The global importance of long-term field stations for biodiversity conservation - an underappreciated value, Russell A. MITTERMEIER, Re:wild Chief Conservation Officer and Chair, IUCN SSC Primate Specialist Group , rmittermeier@rewild.org

A long term rainforest research station in Ranomafana National Park, Madagascar: an engine for lemur conservation, economic development and capacity building. Patricia C. WRIGHT, Stony Brook University, Centre ValBio Research Station, Madagascar. patchapplewright@gmail.com

The Muriqui Project of Caratinga: 41 years of Research, Conservation, Capacity Building, and Policy Impacts. Karen B. STRIER, Vilas Research Professor & Irven DeVore Professor, Department of Anthropology, University of Wisconsin-Madison. kbstrier@wisc.edu

Cocha Cashu: 50 years shaping conservation and science initiatives in Peru. Fanny M. CORNEJO, Executive Director of Yunkawasi. fmcornejo@yunkawasiperu.org

10:30 | Gamboa Grand Ballroom

Sesión oral organizada: Perspectivas sobre la biología básica y las respuestas al cambio global de los bosques tropicales a partir de estudios a muy largo plazo.

Los patrones y procesos ecológicos varían sustancialmente de un año a otro debido a la variación interanual del clima y a las influencias antropogénicas, así como a la dinámica interna estocástica. Los estudios a muy largo plazo que mantienen observaciones consistentes y/o tratamientos experimentales a lo largo de décadas proporcionan información excepcionalmente valiosa sobre la biología básica. También son fundamentales para separar los efectos del cambio antropogénico mundial en curso de otras fuentes de variación interanual. Gracias al apoyo a largo plazo del Instituto Smithsonian de Investigaciones Tropicales, la isla de Barro Colorado y Panamá Central albergan en general un número desproporcionado de estudios importantes y a muy largo plazo sobre los bosques tropicales. Esta sesión destaca algunos de estos estudios clave y cómo han contribuido a nuestra comprensión de los bosques tropicales.

13:30 | Camino de Cruces

Panel de discusión: El legado educativo de BCI y STRI: 100 años y más allá

La estación de campo de la isla Barro Colorado, y el Instituto Smithsonian de Investigaciones Tropicales en general, han desempeñado durante mucho tiempo un papel importante en la formación y educación de científicos tropicales. Esto actualmente incluye un sólido programa de becas y pasantías; un curso de campo de larga duración para estudiantes panameños; una asociación de formación de posgrado con la Universidad McGill; simposios, cursos de capacitación y talleres de desarrollo profesional para la comunidad académica de STRI; y cursos de campo para universidades internacionales.

En esta sesión, los panelistas presentarán primero una visión histórica de los programas académicos de STRI, destacando los cambios en la financiación y la demografía de los pasantes y becarios en los últimos diez años. Esta visión general proporcionará la base para la discusión grupal posterior sobre cómo STRI puede construir a partir de este legado para capacitar mejor a la próxima generación de científicos tropicales y líderes de la ciencia tropical. Las discusiones se llevarán a cabo en pequeños grupos de trabajo para fomentar la participación, con el objetivo general de obtener aportes de la comunidad en general que puedan utilizarse para desarrollar la visión futura de los programas académicos de STRI.

Panelistas:

- Owen MCMILLAN, *Decano Académico*, STRI
- Omar LÓPEZ, *Secretario Técnico*, SENACYT (Sistema Nacional de Investigación de Panamá)
- Carlos JARAMILLO, *científico*, STRI
- Sabrina AMADOR, *científica*, STRI

16:00 | Camino de Cruces

Panel de discusión: El gran valor de las estaciones de campo a largo plazo para la conservación

Organizado por Russell A. Mittermeier, Director de Conservación de Re:wild y Presidente del Grupo de Especialistas en Primates de la CSE de la UICN

A menudo se considera que las estaciones de investigación de campo a largo plazo en los trópicos se centran principalmente en la investigación. Sin embargo, está claro que estas estaciones también tienen un valor de conservación profundo y de gran alcance. Los panelistas discuten sus experiencias basadas en sus roles de liderazgo en las principales estaciones de investigación y destacan las muchas contribuciones que estas estaciones hacen al conocimiento y la conservación de la biodiversidad en general.

Panelistas:

- Patricia C. WRIGHT, Stony Brook University, Centre ValBio Research Station, Madagascar.
- Karen B. STRIER, Vilas Research Professor & Irven DeVore Professor, Department of Anthropology, University of Wisconsin-Madison
- Fanny M. CORNEJO, *Directora Ejecutiva*, Yunkawasi
- Sofia RODRIGUEZ, *Directora Académica*, Organization for Tropical Studies
- Oris SANJUR, *Director Adjunto*, Smithsonian Tropical Research Institute

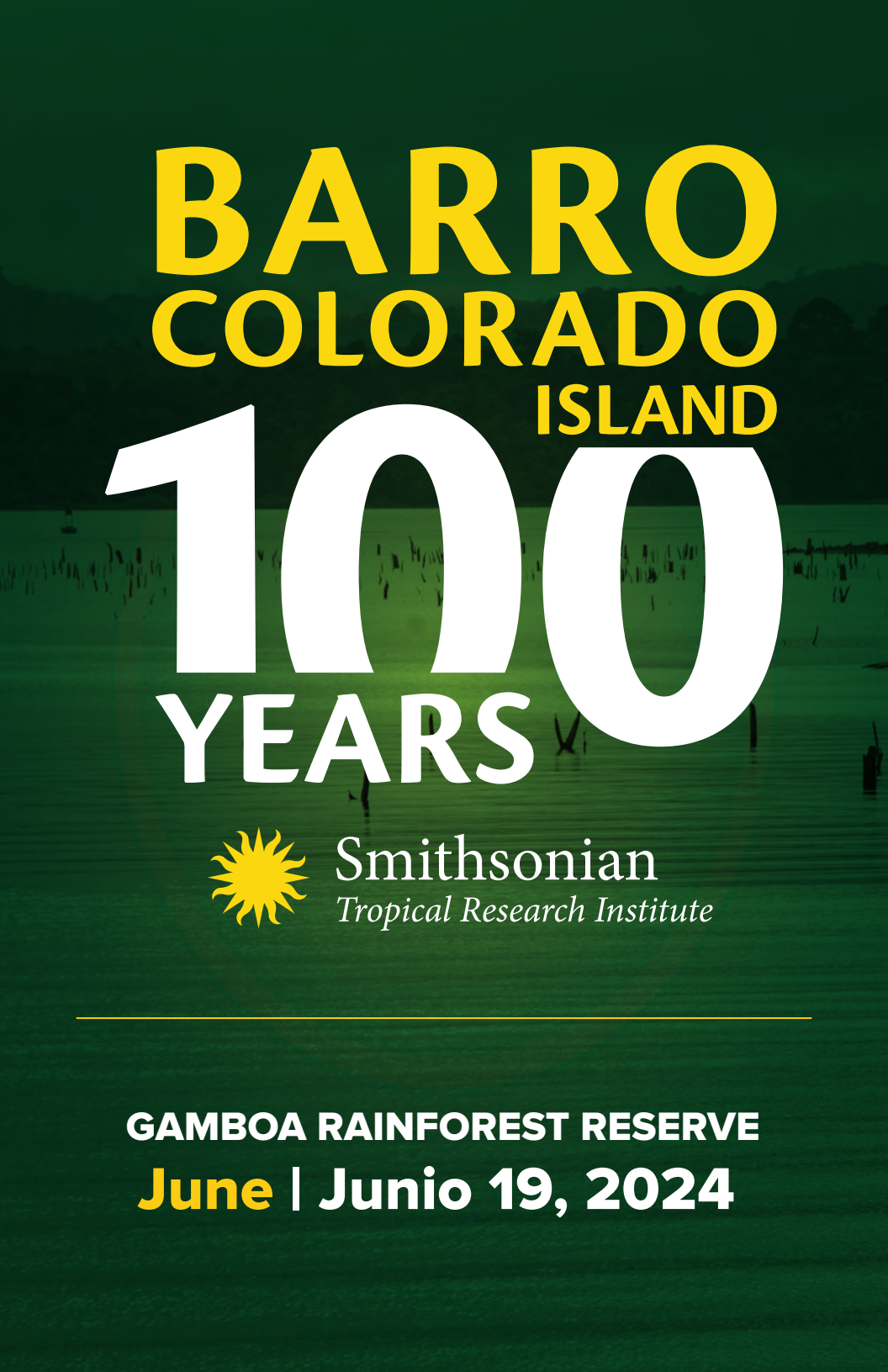
El panel de discusión comenzará con las siguientes ponencias:

La importancia global de las estaciones de campo de larga duración para la conservación de la biodiversidad: un valor subestimado. Russell A. MITTERMEIER, Re:wild Chief Conservation Officer and Chair, IUCN SSC Primate Specialist Group , rmittermeier@rewild.org

Una estación de investigación de la selva tropical a largo plazo en el Parque Nacional Ranomafana, Madagascar: un motor para la conservación de lémures, el desarrollo económico y el desarrollo de capacidades. Patricia C. WRIGHT, Stony Brook University, Centre ValBio Research Station, Madagascar. patchapplewright@gmail.com

El Proyecto Muriqui de Caratinga: 41 años de Investigación, Conservación, Desarrollo de Capacidades e Impactos de Políticas. Karen B. STRIER, Vilas Research Professor & Irven DeVore Professor, Department of Anthropology, University of Wisconsin-Madison. kbstrier@wisc.edu

Cocha Cashu: 50 años dando forma a iniciativas de conservación y ciencia en el Perú. Fanny M. CORNEJO, Executive Director of Yunkawasi. fmcornejo@yunkawasiperu.org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GAMBOA RAINFOREST RESERVE
June | Junio 19, 2024

Time | *Hora*	Room | *Salón*		
	Gamboa Grand Ballroom	**Las Jacarandas**	**Camino de Cruces**
8:30 - 10:00	**Animal Behavior** ***Comportamiento Animal***	**Tree communities: theory and data** ***Comunidades arbóreas: teoría y datos***	**Diverse contributions to tropical forest biology** ***Diversas contribuciones a la biología de los bosques tropicales***
10:00 - 10:30	Coffee break | *Descanso - Gamboa Grand Ballroom, Camino de Cruces, and Las Jacarandas*		
10:30 - 12:00	**The role of plant-enemy interactions in shaping tropical forest communities across environmental gradients** ***El papel de las interacciones entre plantas y enemigos en la configuración de las comunidades de los bosques tropicales a través de gradientes ambientales***	**Anthropological, paleoecological, and marine studies** ***Estudios antropológicos, paleoecológicos y marinos***	**Ecological processes and forest ecosystem functions in dynamic socio-ecological systems: A view from Agua Salud** ***Procesos ecológicos y funciones ecosistémicas forestales en sistemas socioecológicos dinámicos: una visión desde Agua Salud***
12:00 - 13:30	Lunch | *Almuerzo - Corotu Restaurant and Los Guayacanes*		
13:30 - 15:10	**The effects of climate change on large-scale community & ecosystem processes in tropical forests** ***Los efectos del cambio climático en los procesos comunitarios y ecosistémicos a gran escala de los bosques tropicales***	**Animal ecology and evolution** ***Ecología y evolución animal***	**Microbes, chemical ecology, and more** ***Microbios, ecología química y más***
15:15 - 17:45	Coffee break | *Descanso - Gamboa Grand Ballroom and Camino de Cruces*		
15:30 - 17:30	**Poster session (and continuing coffee break)** ***Sesión de posters (y continuación del descanso)***		

8:30 - 10:00 | Gamboa Grand Ballroom
Animal behavior
Comportamiento Animal

8:30 **Eavesdropping micropredators and their unforeseen effects on communication systems.** Ximena E. BERNAL

8:40 **Who is your neighbor? Eavesdropping enemies and nearby signalers in mixed species assemblages.** Alex TRILLO

8:50 **The role of heterospecifics and habitat on signal design.** Katherine GONZALEZ

9:00 **Call-timing responses to frequency- and amplitude-modulated stimuli depend on immediate acoustic context in a frog with similarly modulated calls.** Luke C. LARTER

9:10 **Humans and animals share acoustic preferences.** Logan S. JAMES

9:20 **Relationship formation in vampire bats without forced proximity.** M. May DIXON

9:30 **The impacts of light on frugivorous bat foraging behavior.** Lauren A. NORWOOD

9:35 **Bat predation on sleeping birds: a novel foraging strategy for an eavesdropping specialist?** Mary Heather B. JINGCO

9:40 **Unraveling the sexual phenotype of a tropical hummingbird.** Jay Jinsing FALK

9:50 **The evolution of nocturnal behavior in bees.** William T. WCISLO

8:30 - 10:00 | Las Jacarandas
Tree communities: theory and data
Comunidades arbóreas: teoría y datos

8:30 **The seeds of coexistence: Seed chemistry explains co-occurrence of *Psychotria* species along a moisture gradient.** Gerald F. SCHNEIDER

8:40 **Resistance gene diversity and the eco-evolutionary dynamics of tropical tree seedlings.** James H. MARDEN

8:50 **Eight new species of fungi in the genus Calonectria and their role as regulators of plant diversity on BCI.** Hernán D. CAPADOR-BARRETO

9:00 **Understanding disease-driven density dependence and coexistence.** Marco VISSER

9:10 **Janzen-Connell effects and habitat-induced aggregation synergistically promote species coexistence.** Daniel J. B. SMITH

9:20 **Spatial repulsion among conspecific adult trees on BCI.** Michael KALYUZHNY

9:30 **A spatial signal of niche differentiation among woody plants in tropical forests.** Rafael D'ANDREA

9:40 **Non-neutral forest gap dynamics promote tree species and functional diversity in BCI.** Annette OSTLING

9:50 **Symmetric intransitive loop competition can lead to stable coexistence for odd but not even numbers of species.** Daniel P. MAES

8:30 - 10:00 | Camino de Cruces
Diverse contributions to tropical forest biology
Diversas contribuciones a la biología de los bosques tropicales

8:30 **The effects of seasonality on the expression and evolution of antimicrobial peptides in the Slender Anole (*Anolis apletophallus*)** Yanileth F. LOPEZ-TACOAMAN

8:35 **A thermoconforming forest lizard alters heat-shock protein network expression in response to acute thermal stress.** Kelly Lin WUTHRICH

8:40 **Lizard gut microbiomes mediate host survival during environmental change.** Claire E. WILLIAMS

8:50 **Parasite removal alters thermal tolerance in a tropical lizard.** Leah BAKEWELL

9:00 **Understanding the interplay between temperature and inheritance shaping iridescence in the Neotropical butterfly *Parides sesostris*.** Leo Tomás CAMINO CEDEÑO

9:05 **The two cryptic species of *Trema micrantha* of Barro Colorado Island: A model for tropical tree speciation?.** Camila PIZANO

9:15 **Understanding the value of the forests of the Darien, Panama through the participatory establishment of a permanent forest plot with an Emberá territory.** Maximiliane JOUSSE

9:25 Fallen angels: Epiphyte's struggle for survival from the understory of a rainforest in Panamá. Mateo FERNANDEZ LUCERO

9:35 Tempo and mode in secondary succession: Changes of aboveground biomass in Coiba Island, Panama. Edgardo I. GARRIDO-PEREZ

9:40 Variation in root water storage capacity among tropical trees. Brett T. WOLFE

9:50 Biogeochemical processes in Lutz Creek and Conrad Trail Stream, Barro Colorado Island. Robert F. STALLARD

10:00 Coffee Break | *Descanso*

10:30 - 12:00 | Gamboa Grand Ballroom
The role of plant-enemy interactions in shaping tropical forest communities across environmental gradients
El papel de las interacciones planta-enemigo en la configuración de comunidades de los bosques tropicales a través de gradientes ambientales

10:30 Effects of insect herbivores and plant pathogens on plant diversity and density dependence across a tropical precipitation gradient. Owen T. LEWIS

10:40 Patterns in foliar disease incidence in the tree seedling community across the precipitation gradient in Panama. Valerie R. MILICI

10:50 Ecometabolomics, environmental gradients and the growth-defense trade-off in tropical trees. Dale L. FORRISTER

11:00 Plant metabolites contribute to density-dependent performance, and hence niche partitioning, within communities and reflect clines in abiotic and biotic selection over environmental gradients. Brian E. SEDIO

11:10 Exploring latitudinal trends in plant-insect interactions and plant specialized metabolites. Martin VOLF

11:20 Escaping the enemy: Spatial ecology of plant-insect interactions in tropical forests. Patrick G. CANNON

11:30 Seedling insect herbivory along succession in a Neotropical forest. Damla CINOĞLU

11:40 Effects of natural enemies on seedling community dynamics during the secondary succession of Panamanian rainforests. Anita WEISSFLOG

11:50 The interplay between defaunation and phylogenetic diversity affects leaf damage by natural enemies in tropical plants. Carine EMER

10:30 - 12:00 | Las Jacarandas
Anthropological, paleoecological, and marine studies
Estudios antropológicos, paleoecológicos y marinos

10:30 **Interacciones entre grupos humanos y el paisaje en Panamá durante el Holoceno medio y tardío a través del estudio de las materias primas líticas y el análisis de huellas de uso: Retos y perspectivas a futuro.** Arturo GARCÍA DE LEÓN

10:35 **Panamanian traditional rope-tension drums: A global history of adaptation and resilience in the heart of the tropics.** Samuel ROBLES

10:40 **A Pleistocene fossil wood flora from the Gigante Peninsula and comparisons with the modern-day flora.** Camila MARTÍNEZ

10:50 **Exploring the Eocene paleobotanical record of Panama.** Oris RODRIGUEZ REYES

11:00 ***Retidiporites magdalenensis:* A paleopalynological enigma from the Neotropics and its potential connection to CAM photosynthesis in Bromeliaceae.** Maurcio LEÓN-CARREÑO

11:05 **Understanding the Upper Cretaceous tropical seas: A palaeoceanographic study of the epicontinental sea of the Upper Cretaceous of Colombia.** David Eduardo CARO CARO

11:10 **Sister species an ocean apart: Investigating the drivers of coral reef fish microbiome composition across the Isthmus of Panama.** Laura L. LARDINOIS

11:15 **Who, where, when, and why: Elasmobranch diversity across estuaries of the Tropical Eastern Pacific coast of Panama and Costa Rica scrutinized using eDNA.** Helio QUINTERO ARRIETA

11:25 **Novel insights into coral coexistence through early life competition studies - Thanks to vital stains.** Carrie SIMS

11:35 **Antioxidants enhance coral resilience to thermal stress.** Maria Alejandra CHACON BUITRAGO

11:45 **Visualizing and quantifying *Pocillopora* coral bleaching in Panama's ETP during El Niño with 3D Models and Orthomosaics.** Ilana S. VARGAS

10:30 - 12:00 | Camino de Cruces
Ecological processes and forest ecosystem functions in dynamic socio-ecological systems: A view from Agua Salud
Procesos ecológicos y funciones de los ecosistemas forestales en sistemas socioecológicos dinámicos: Una mirada desde Agua Salud

10:30 Agua Salud: Sustainability science for the 21st century. Jefferson Scott Hall

10:40 Feedback loops drive ecological succession: Towards a unified conceptual framework. Michiel VAN BREUGEL

10:50 Tropical forest carbon sequestration accelerated by nutrients. Wenguang TANG

11:00 Changes in soil microbial diversity with nutrient addition in a rapidly growing tropical forest. Kristin SALTONSTALL

11:10 Arbuscular mycorrhiza in native timber plantations in the Panama Canal watershed. Raquel M. RODRÍGUEZ-RODRÍGUEZ

11:20 Assessment of ground-dwelling mammals on timber plantations embedded in the landscape mosaic of Central Panama. Claudio Manuel MONTEZA-MORENO

11:30 Contributions of Agua Salud catchment scale experiments to understanding tropical forest hydrologic ecosystem services – Past findings and future directions. Melinda D. DANIELS

11:40 Citizen science watershed resilience: Student and teacher-led exploration of land use change and stream health. Andrea F MILLER

11:50 Local socioeconomic dynamics, governance and perceptions regarding the Rohr Reforestation Initiative in the Comarca Ngäbe-Buglé. Jazmín GONZALES TOVAR

12:00 Lunch | *Almuerzo*

13:30 - 15:10 | Gamboa Grand Ballroom
The effects of climate change on large-scale community & ecosystem processes in tropical forests
Los efectos del cambio climático en los procesos comunitarios y ecosistémicos a gran escala en los bosques tropicales

13:30 The climate of Barro Colorado Island: 95 years of monitoring. Steven PATON

13:40 Land-atmosphere interactions: The response of a Barro Colorado Island to water stress over multiple temporal scales. Matteo DETTO

13:50 **Drivers of soil carbon emission in warmed tropical soil.** Andrew Thomas NOTTINGHAM

14:00 **Seasonal and experimental drying effects on tropical forest soil respiration: experimental and modeling approaches.** Lee H. DIETTERICH

14:10 **Effects of moisture and density-dependent interactions on tropical tree diversity.** Edwin LEBRIJA-TREJOS

14:20 **Response of tropical tree species to increased temperatures and elevated CO^2 concentrations.** Klaus WINTER

14:30 **The integrated resistance of tropical trees to heat and drought stress.** Louis SANTIAGO

14:40 **Lianas cool down forest understories but increase light availability.** Kasper COPPIETERS

14:50 **El Niño events, host plant growth, and migratory butterfly abundance in a changing climate.** Robert B. SRYGLEY

15:00 **Using the vertical dimension of forests to test tradeoffs and principles of community ecology.** Jane LUCAS

13:30 - 15:10 | Las Jacarandas
Animal ecology and evolution
Ecología y evolución animal

13:30 **Coacting effects of precipitation and tropical forest fragmentation on the structure and foraging niches of mixed-species foraging aggregations.** Michael CASTAÑO-DIAZ

13:40 **How the environment alters network structure in mixed-species groups of army-ant-following birds.** Mary DE AQUINO

13:50 **The impact of climate variation on the inter-specific dynamics of locally adapted *Aedes aegypti* and invasive *Aedes albopictus*.** Julie I. R. LABAU

14:00 **The influence of lightning on insect and fungal dynamics within the Barro Colorado Nature Monument.** Kane A. LAWHORN

14:10 **Lightning disturbance shapes local avifaunal communities in the Barro Colorado Nature Monument.** Matthew W. CHMIELEWSKI

14:20 **Too hot to handle? The thermal ecology of insect seed predators in tropical rainforests.** Joshua Aaron JONES

14:25 **Composition of arthropod rain in a tropical forest.** Andrew R. SEILER

14:35 **The importance of dorsal landmarks for navigation in dark and cluttered environment by a nocturnal bee.** Andre SCHEEPERS

14:45 **Notas de la biología y parásitos de abejas en Panamá** Hermógenes FERNANDEZ-MARIN

14:55 **Llevando el laboratorio a la práctica: Experiencias con felinos silvestres en Panamá.** Josue ORTEGA

13:30 - 15:10 | Camino de Cruces
Microbes, chemical ecology, and more
Microbios, ecología química y más

13:30 **Comunidades bacterianas en la filosfera: Un análisis de la gimnosperma epífita *Zamia pseudoparasitica*.** Lilisbeth RODRÍGUEZ-CASTRO

13:40 **Uncovering the ecology and genomics of predatory amoebae in tropical forest soils.** Rachel M. SHEPHERD

13:45 **Exploring fungal rhizomorph deterrence of ants in Panama.** Alice BOSSARD

13:50 **Fungal alkaloids mediate defense against bruchid beetles in field populations of an arborescent Ipomoea.** Alberto PRADO

13:55 **Paleocene origin of a streamlined digestive symbiosis in leaf beetles.** Hassan SALEM

14:05 **The evolution of insect pheromone biosynthesis: A case study in *Heliconius* butterflies.** Kathy DARRAGH

14:15 **Interacting effects of moisture and biotic interactions on seedling recruitment in tropical forests.** Hilario ESPINOSA

14:25 **The role of frequency-dependent selection in controlling the expansion of clonal aggregations in the tropical forest understory: Insights from a decade-long experiment.** Eloisa LASSO

14:35 **Realizing the potential of native microbes in the agricultural sector: From basic studies of fungi interactions to sustainable management of diseases in the tropical tree crops coffee and cacao.** Luis C. MEJIA

14:45 **Cultivating resilience in the tropics: Exploring *Theobroma cacao* genotype-mycobiome interactions for disease management.** Hilda E. CASTILLO

14:55 **Biological control as a conservation science: From promise to action.** Kris A.G. WYCKHUYS

15:15 Coffee Break | *Descanso*

15:30 - 17:30 - Gamboa Grand Ballroom
Poster session (and continuing coffee break)
Sesión de posters (y continuación del descanso)

P1 **Riqueza, abundancia y diversidad de murciélagos en los alrededores del hotel Summit Rainforest Resort & Golf Panamá, provincia de Panamá.** Melissa LÓPEZ GONZÁLEZ

P2 **Social information use in foraging *Artibeus jamaicensis*.** Brandi CHRISTIANO

P3 **Patrones territoriales en el murciélago de ventosas, *Thyroptera tricolor*.** Silvia CHAVES-RAMÍREZ y Mariela SÁNCHEZ-CHAVERRÍA

P4 **Prey-capture techniques of an ant-eating jumping spider, *Corythalia pulchra* (Araneae: Salticidae), from Panama.** Jonah NAUGLE

P5 **COVID-19 induced lockdown: assessment of ground-dwelling wildlife responses to reduced human presence on Barro Colorado Island.** Claudio Manuel MONTEZA-MORENO

P6 **La contribución de las aves a la dispersión de semillas en áreas degradadas.** Nathaly Elizabeth PONCE Chilan

P7 **¿Varían las recompensas para las hormigas según la defensa que proveen a la planta hospedera?** Maikol GUEVARA PEREZ

P8 **Plant-pollinator interaction network between diurnal Lepidoptera and flowering plants in the Atlantic Forest.** Alessandra MIKICH

P9 **Swollen-thorn acacias invested more in their defending ants during El Niño 2023.** Cristian MOLINA

P10 **Trial using live vaccination in chytridiomycosis-susceptible *Atelopus glyphus* leads to worse disease outcomes than controls.** Joseph D. MADISON

P11 **The ecological and genetic basis of colorful signal evolution in the slender anole (*Anolis apletophallus*).** Elizabeth G. HOFFMAN

P12 **Ecological correlates of a female-limited dorsal color pattern polymorphism in the slender anole (*Anolis apletophallus*).** John V. NGUYEN

P13 **Knockdown of gene regulatory network components in *Heliconius* butterflies using dsiRNA.** Paola Angélica SOTO MÉNDEZ

P14 **Unveiling reference genes for gene expression analyses in *Heliconius erato lativitta*.** Paola CALDERON

P15 **Development of taxon-specific molecular probes to track the density and distribution of phytopathogens in tropical forests.** Cecilia A. WEBBER

P16 **How are phytopathogenic fungi distributed across tree species? Implications for the role of phytopathogens in the maintenance of forest diversity.** Chloe N. INSLER

P17 **Cepas de *Calonectria spp.* aisladas de *Virola nobilis:* morfología, crecimiento y patogenicidad** Omayra MELÉNDEZ P.

P18 **Caracterización de genes de resistencia en *Virola nobilis* de la isla Barro Colorado: Hacia una mejor comprensión de la dinámica poblacional.** Sergio CAÑÓN

P19 **Is there turnover in fungal pathogens from the forest floor to canopy and across ontogeny? Implications for the role of phytopathogens in the maintenance of forest diversity.** Laurel SCHMIDT

P20 **Achy Breaky Hearts: Investigating microbial-driven internal decay in tropical trees.** Rosa K. MASON

P21 **Achy Breaky Hearts: Investigando la pudrición interna mediada por microbios en árboles tropicales.** Fransuá Mar OTERO MARGARY

P22 **Patrones de abundancia en insectos que se alimentan de semillas de huéspedes específicos potencialmente competidores.** Conny HERNÁNDEZ OTERO

P23 **How does nutrient content, fruit removal rate and risk of attack shape fruit defense?** Elsa Mini JOS

P24 **Incertidumbre en ecuaciones alométricas de monocultivo aplicadas a cultivos mixtos de árboles nativos en Panamá.** Edwin H. GARCÍA

P25 **Exploring the biomineralization of silica bodies in *Selaginella*.** Priscila Damaris LOPEZ

P26 **Diurnal variation in photosynthetic responses of *Calophyllum inophyllum* to temperature shifts: Implications for tropical species adaptation.** Juan Camilo MEJíA MEDINA

P27 **Nutrient efficiencies in three tropical species as part of the Agua Salud Research Project.** Maria Alejandra GALLEGOS KOYNER

P28 **Causal relationships between tree functional traits, assimilation, and life history strategies.** Minh Chau N. HO

P29 **Coexistence through life history variations in an explicit patch age model.** Jon R. STAGGS

P30 **Re-examining the phylogenetic structure of the BCI forest community reveals overdispersion across spatial scales.** Ryan R. HERNANDEZ

P31 **The emergence of phylogenetic clusters in stochastic niche forest communities.** Satavisha DE

P32 **The impacts of long-term soil warming on nitrogen-fixation in tropical understory trees in Panama.** Andrew T. NOTTINGHAM

P33 **Past human mobility in the Lower Central American Landbridge: preliminary results.** Yajaira NUNEZ CORTES

P34 **Archaeology of childhood: isotopic approaches to breastfeeding and weaning practices in three pre-columbian panamanian populations.** Veronica PACE

P35 **Fossil Leaves from the Gigante Peninsula.** Diana Karen PÉREZ LARA

P36 **A stylistic and typological analysis of the poorly known La Mula pottery from Cerro Juan Díaz first settlers.** Benoit DESJARDINS

P37 **Digitization and morphometric analysis of modern pollen grains of the Rosaceae family.** Brenda OROSCO

P38 **Efecto del afloramiento en la abundancia y prevalencia de parásitos en peces serránidos del golfo de Panamá.** Luis Carlos RODRÍGUEZ C.

P39 **Effecto de antioxdantes en la capacidad fotosíntetica de *Pocillopora verrucosa*, como propuesta para la conservación de arrecifes de corales.** Eunice Tapia MORENO

P40 **Cambios en la eficiencia fotosintética de *Pocillopora spp.* en el Pacifico Este Tropical de Panamá ante el reciente fenómeno del Niño.** Marianela G. CAMARENA VARGAS

P41 **Aumentos estacionales de clorofila podrían explicar las migraciones de grandes pelágicos en la región oeste de Coiba, Golfo de Chiriquí.** Carmen PÉREZ MEDINA

P42 **Respuesta celular ante procesos de estrés térmico y salino en *Pocillopora grandis* y *Pocillopora cf. verrucosa* del pacifico panameño.** Mariana L FERNÁNDEZ

P43 **Exploring the effects of salinity and temperature stress on the physiology of *Pocillopora grandis* from the Panamanian Eastern Tropical Pacific.** Kyaralind VASQUEZ-LIRIANO

P44 **Exploring mesophotic coral reef diversity on a Caribbean seamount using environmental DNA.** Luisa MEISTER

P45 **Plasticidad de nichos tróficos en especies hermanas de peces separadas por el Istmo de Panamá.** Javiera MORA SCHEUER

P46 **En busca de la especie en peligro crítico de extinción (*Pristis pristis*) en el POT de Panamá usando el ensayo altamente sensible, Digital Droplet PCR.** Yaliana H. CHICHACO

P47 **Explorando la diversidad y distribución de elasmobranquios en el Pacífico de Panamá por medio de ADN ambiental en sedimento marino (sedDNA).** María Andrea LACAYO-GONZÁLEZ

P48 **Patrones de diversidad taxonómica y filogenética en comunidades marinas a lo largo de un gradiente latitudinal.** María Alejandra SÁNCHEZ

P49 **Estudio de la abundancia y distribución del sargazo en Playa la Angosta y Nombre de Dios, Colón, Panamá.** Kevin GOMEZ CORTES

P50 **Respuestas de los tiburones a los cambios climáticos del pasado en el Pacífico panameño: El golfo de Panamá como caso de estudio.** Irene GARCÍA PÉREZ

P51 **Language Exchanges/Intercambio de idiomas.** Kathy DARRAGH, Olivia MILLOWAY, Nicole SMITH-GUZMÁN, Carmen SCHLOEDER, Rachel PAGE

10:30 | Gamboa Grand Ballroom
Organized Oral Session: The role of plant-enemy interactions in shaping tropical forest communities across environmental gradients
Organized by Anita WEISSFLOG, Damla CINOGLU, Liza COMITA, and Daisy DENT

Ecologists have long recognised the importance of biotic interactions in tropical forests. In particular, there is increasing recognition that plant-enemy interactions play a critical role in shaping plant communities, both in the tropics and beyond. Theoretical and empirical studies have shown that interactions between plants and their pathogens and herbivores can influence the composition, diversity, and dynamics of tropical tree communities. Recent studies suggest that these interactions can shift across environmental gradients, e.g., with rainfall, and as a result of human disturbance, e.g., with fragmentation or in secondary forests. In an era of global change, it is critical that we understand how the mechanisms that shape tropical plant communities change with human disturbance and shifting climates. We will bring together a diverse range of speakers with expertise in tropical plant-enemy interactions. We will present a series of forward-looking talks to address the role of in these interactions in shaping forest composition across gradients of forest degradation, rainfall and across secondary forest succession. We aim to highlight novel methodological and analytical techniques and identify key areas for interdisciplinary research that will further our understanding of how plant-enemy interactions will continue to shape tropical forests in the long-term.

10:30 | Camino de Cruces
Organized Oral Session: Ecological processes and forest ecosystem functions in dynamic socio-ecological systems: A view from Agua Salud
Organized by Jefferson HALL and Michiel VAN BREUGEL

Agua Salud was set up to study the ecosystem services provided by seasonal tropical forests in human-modified landscapes and how they change with land use and climate change. Research goes beyond attempts to quantify ecosystem services where researchers strive to understand ecosystem function in dynamic socio-ecological systems with the goal of building the next generation of models that will afford improved predictions of ecosystem services in an uncertain future and across the tropics. Today Agua Salud is a STRI Facility that hosts researchers from around the world who wish to take advantage of research and data infrastructure to advance collaborative science. Agua Salud serves as a model for sustainability science at STRI and has seeded new multidisciplinary research and action across Panama.

The session will celebrate the breadth of Agua Salud science with talks ranging from Basic, Basic use inspired, and Applied research with an emphasis on recent research findings, including how they influence thought and practice beyond Agua Salud. Agua Salud leverages research from Barro Colorado Island, allowing different types of studies in a human dominated landscape more akin to the tropical forest landscape of the future.

13:30 | Gamboa Grand Ballroom
Organized Oral Session: The effects of climate change on large-scale community and ecosystem processes in tropical forests stations for conservation
Organized by Stefan A. SCHNITZER

Climate change is affecting ecosystems worldwide, and tropical forests are no exception. Detecting the signal of climate change and the population, community, and ecosystem level responses in tropical forests, however, requires data spanning large temporal and spatial scales. In this session, we will explore the long-term abiotic changes that are occurring on BCI and in central Panama, and the population, community, and ecosystem responses to those climatic changes.

10:30 | Gamboa Grand Ballroom
Sesión Oral Organizada: El papel de las interacciones planta-enemigo en la configuración de comunidades de los bosques tropicales a través de gradientes ambientales
Organizado por Anita WEISSFLOG, Damla CINOGLU, Liza COMITA y Daisy DENT

Los ecologistas han reconocido desde hace mucho tiempo la importancia de las interacciones bióticas en los bosques tropicales. En particular, cada vez se reconoce más que las interacciones entre plantas y enemigos desempeñan un papel fundamental en la configuración de las comunidades vegetales, tanto en los trópicos y más allá. Los estudios teóricos y empíricos han demostrado que las interacciones entre las plantas y sus patógenos y herbívoros pueden influir en la composición, diversidad y dinámica de comunidades de árboles tropicales. Estudios recientes sugieren que estas interacciones pueden cambiar a través de gradientes ambientales, por ejemplo, con las lluvias, y como resultado de la perturbación humana, por ejemplo, con la fragmentación o en los bosques secundarios. En una era de cambio global, es fundamental que entendamos cómo cambian los mecanismos que dan forma a las comunidades de plantas tropicales con las perturbaciones humanas y los climas cambiantes. Reuniremos a una amplia gama de oradores con experiencia en las interacciones entre plantas tropicales y enemigos. Presentaremos una serie de charlas con visión de futuro para abordar el papel de estas interacciones en la configuración de la composición de los bosques a través de gradientes de degradación forestal, precipitaciones y a través de la sucesión de bosques secundarios. Nuestro objetivo es destacar nuevas técnicas metodológicas y analíticas e identificar áreas clave para la investigación interdisciplinaria que mejorarán nuestra comprensión de cómo las interacciones planta-enemigo continuarán dando forma a los bosques tropicales a largo plazo.

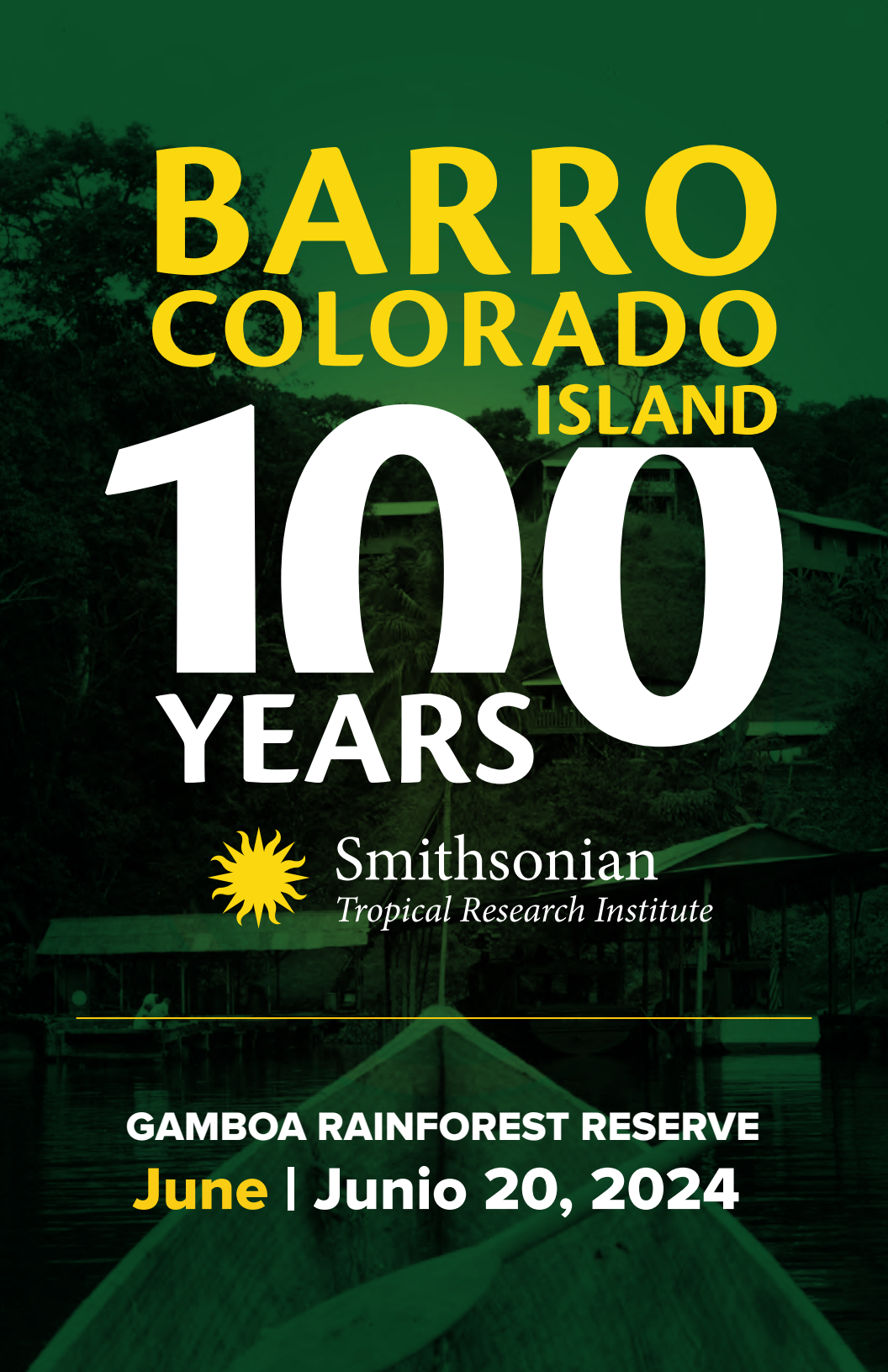
10:30 | Camino de Cruces
Sesión Oral Organizada: Procesos ecológicos y funciones de los ecosistemas forestales en sistemas socioecológicos dinámicos: Una mirada desde Agua Salud
Organizado por Jefferson HALL y Michiel VAN BREUGEL

Agua Salud se creó para estudiar los servicios ecosistémicos que brindan los bosques tropicales estacionales en paisajes modificados por el hombre y cómo cambian con el uso de la tierra y el cambio climático. La investigación va más allá de los intentos de cuantificar los servicios ecosistémicos, donde los investigadores se esfuerzan por comprender la función de los ecosistemas en sistemas socioecológicos dinámicos con el objetivo de construir la próxima generación de modelos que permitan mejores predicciones de los servicios ecosistémicos en un futuro incierto y en los trópicos. Hoy en día, Agua Salud es una instalación de STRI que alberga a investigadores de todo el mundo que desean aprovechar la infraestructura de investigación y datos para avanzar en la ciencia colaborativa.

Agua Salud sirve como modelo para la ciencia de la sostenibilidad en STRI y ha sembrado nuevas investigaciones y acciones multidisciplinarias en todo Panamá. La sesión celebrará la amplitud de la ciencia de Agua Salud con charlas que van desde la investigación básica, inspirada en el uso básico y aplicada, con énfasis en los hallazgos de investigaciones recientes, incluida la forma en que influyen en el pensamiento y la práctica más allá de Agua Salud. Agua Salud aprovecha la investigación de la isla de Barro Colorado, lo que permite diferentes tipos de estudios en un paisaje dominado por el ser humano más parecido al paisaje de bosque tropical del futuro.

13:30 | Gamboa Grand Ballroom
Sesión Oral Organizada: Los efectos del cambio climático en los procesos comunitarios y ecosistémicos a gran escala en los bosques tropicales
Organizado por Stefan A. SCHNITZER

El cambio climático está afectando a los ecosistemas de todo el mundo, y los bosques tropicales no son una excepción. Sin embargo, la detección de la señal del cambio climático y las respuestas a nivel de población, comunidad y ecosistema en los bosques tropicales requiere datos que abarquen grandes escalas temporales y espaciales. En esta sesión, exploraremos los cambios abióticos a largo plazo que están ocurriendo en BCI y en el centro de Panamá, y las respuestas de la población, la comunidad y el ecosistema a esos cambios climáticos.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June | Junio 20, 2024

Time	*Hora*	Room	*Salón*
		Gamboa Grand Ballroom	
8:30 - 9:45		A conversation with Cristián Samper, Managing Director and Leader of Nature Solutions at the Bezos Earth Fund *Una conversación con Cristián Samper, Director General y Líder de Nature Solutions en el Bezos Earth Fund*	
9:45 - 10:15		Coffee break | *Descanso*	
10:15 - 12:00		The potential of modern technologies to advance tropical forest research *El potencial de las tecnologías modernas para avanzar en la investigación sobre los bosques tropicales*	
12:00 - 13:30		Lunch | *Almuerzo - Corotu Restaurant and Los Guayacanes*	
13:30 - 15:00		Looking to the Future at BCI and Beyond *Mirando hacia el futuro en BCI y más allá*	
15:00 - 16:00		Poster session (and coffee break) *Sesión de posters y descanso*	
16:00 - 17:30		The Next “Big Plot”: what new massive data collection campaign can transform tropical forest science? *La próxima "gran parcela": ¿qué nueva campaña de recopilación masiva de datos puede transformar la ciencia de los bosques tropicales?*	

8:30 - 9:45 | Gamboa Grand Ballroom
A conversation with Cristián Samper, Managing Director and Leader of Nature Solutions at the Bezos Earth Fund
Una conversación con Cristián Samper, Director General y Líder de Nature Solutions en el Bezos Earth Fund

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9:45 Coffee Break | *Descanso*

10:15 - 12:00 | Gamboa Grand Ballroom
The potential of modern technologies to advance tropical forest research
El potencial de las tecnologías modernas para avanzar en la investigación sobre los bosques tropicales

10:15 Genetic and species diversity of tropical trees on Barro Colorado Island: Four decades of insights and future directions. Andy JONES

10:30 Novel approaches for measuring biodiversity in tropical forest. Daisy DENT

10:45 Artificial intelligence for natural environments: Automated detection and classification of insects in the rainforest canopy. Laurel B. SYMES

11:00 Building a science of the sociome. Meg CROFOOT

11:15 PollenGeo: Palynology moving into the digital world. Carlos JARAMILLO

11:30 Characterizing heterogeneity in tropical forest functional diversity using remote sensing. Elsa ORDWAY

11:45 The impacts of of deforestation and degradation on tropical forest's sensitivity to extremes: An integrated model and remote sensing approach. Marcos LONGO

2:00 Lunch | *Almuerzo*

13:30 - 15:00 | Gamboa Grand Ballroom
Looking to the Future at BCI and Beyond
Mirando hacia el futuro en BCI y más allá

13:30 The 2024 Gamboa Bioblitz: Results of a rapid participatory biological inventory. Steven PATON

13:35 From camera traps to trap-lining: Using motion-detection cameras to monitor foraging behaviour of individual butterflies. Denise Dalbosco DELL'AGLIO

13:40 Linking seed dispersers' movement to seed dispersal patterns: Insights from movement ecology. Noelle G. BECKMAN

13:50 **Using Internet of Things (IoT) networks to track animals in Peru and Panamá.** Roland KAYS

14:00 **Quantifying landscape-level tropical forest dynamics on Barro Colorado Island, Panama at fine temporal, spatial, and potentially taxonomic resolution using repeat drone photogrammetry.** Helene C. MULLER-LANDAU

14:10 **Tracking individual tree crowns across time using widely available AI models and high resolution drone imagery.** Vicente VASQUEZ

14:20 **Giant trees and lightning: Expected deaths, unexpected benefits, and new directions.** Evan M. GORA

14:30 **Innovating ambition to action: Technological implementation, data integration and multilateralism for the Global Biodiversity Framework.** Peter R. HOULIHAN

14:40 **GEO-TREES: A global forest biomass reference system.** Stuart DAVIES

14:50 **PANGEA: A scoping study for a NASA tropical forest terrestrial ecology campaign.** Elsa ORDWAY

15:00 - 16:00 | Gamboa Grand Salon
Poster session (and coffee break)
Sesión de posters y descanso

P1 **Next-gen insect monitoring: AMI systems and insect monitoring on Barro Colorado Island.** Adolfo ALBA POLANCO

P2 **Next steps in insect monitoring: the prospects of metabarcoding.** Eduardo NAVARRO-VALENCIA

P3 **Digitization and morphological analysis of modern pollen samples of the subfamily Asteroideae (Asteraceae) from northern South America.** Thiago WOOD PIRES

P4 **Digitization of palynological samples of Bombacaceae family from the Graham's collection.** Natalia OVALLE ROMERO

P5 **Building the basis for automated species identification of tropical plants from hyperspectral and laser scanning data.** Juan C. OSORIO–OSPINA

P6 **Quantifying carbon fluxes from tree mortality and damage through the integration of drone photogrammetry and ground field surveys.** Luisa F. GÓMEZ-CORREA

P7 **Quantifying patterns of lightning-caused canopy disturbances in the Barro Colorado Island with the integration of drone imagery and field surveys.** Evan M. GORA

P8 **Topography as a barrier against fire spread in the Ecuadorian Andes.** Pablo SARANGO HIDALGO

P9 **Increasing liana density reduces canopy height and carbon storage potential in an old growth Neotropical forest.** David M. DEFILIPPIS

P10 **Soil water availability and depth of tree and liana root water extraction across the Panamanian Isthmus during the 2024 extreme El Niño.** Alfonso J. ZAMBRANO

P11 **Observation-informed representation of tropical forest diversity at regional scale in terrestrial biosphere models.** Marcos LONGO

P12 **Plant defense chemistry of woody seedlings varies with life history.** Damla CINOGLU

P13 **Estudio de comunidades de hongos endófitos foliares asociados a 16 especies de plantas muestreadas en cafetales de Renacimiento y Parque internacional La amistad, Chiriquí, Panamá.** Karina VIQUEZ RIOS

P14 **You eat what you hear: Hearing sensitivity as an underlying mechanism for niche differentiation in gleaning bats.** Inga GEIPEL

P15 **Panama tropical forest soils as a model field system for ecological studies of protists.** Rachel M. SHEPHERD

P16 **Análisis de capacidades y logros funcionales en la iniciativa de reforestación de la Comarca Ngäbe-Buglé a través del enfoque de *Amartya Sen*.** Karen Alejandra CÁRDENAS

P17 **The Bacurú Drõa plot, Darien: Bringing BFDP science to people.** Alexis ORTEGA

P18 **Connecting communities with nature: STRI Education & Public Program Initiatives.** Jimena PITTY

16:00 - 17:30 | Gamboa Grand Ballroom

The Next "Big Plot": what new massive data collection campaign can transform tropical forest science?

La próxima "gran parcela": ¿qué nueva campaña de recopilación masiva de datos puede transformar la ciencia de los bosques tropicales?

16:00 **Opening words on "the next big plot".** Josh TEWKSBURY and Stuart DAVIES

16:05 **BCI as a hub for globally distributed experiments.** Jim DALLING

16:10 **Rainforest Snapshot.** Roland KAYS

16:15 **BIO-Acoustics.** Laurel SYMES

16:20 **FOREST-UP: Forest Understanding and Conservation through Plant Metabolites.** María-José ENDARA

16:25 **A long-term monitoring programme for rainforest insects.** Owen LEWIS

16:30 **Deep Dive: a global exploration of tropical soil chemistry and food webs.** Jane LUCAS

16:35 **The EvoGEO (EVOlutionary dynamics Global Earth Observatory) initiative.** Andy JONES

16:40 **Species-specific monitoring of all woody plants on all BCI using drones, hyperspectral imaging, laser scanning, and AI.** Helene C. MULLER-LANDAU

16:45 **Discussion**

8:30 | Gamboa Grand Ballroom
A conversation with Cristián Samper, Managing Director and Leader of Nature Solutions at the Bezos Earth Fund
A conversation with Cristián Samper, Managing Director and Leader of Nature Solutions at the Bezos Earth Fund, who will be interviewed by STRI Research Associates Ximena Bernal (Purdue University) and Eloisa Lasso (Coiba-AIP). Samper's expertise in leading widely renowned biodiversity and conservation organizations, including STRI, will serve as the foundation for a vibrant conversation about the future of scientific research on tropical forests and reefs addressing the challenges and opportunities to fund this work.

10:15 | Gamboa Grand Salon
Organized oral session: The potential of modern technologies to advance tropical forest research
Technological advances are enabling the collection and analysis of ever larger and more detailed datasets on tropical organisms and ecosystems. These include not only advances in hardware, but also advances in artificial intelligence (AI). Here, speakers present case studies of how some of the most promising technologies are being applied today, and discuss the potential for further insights.

16:00 | Gamboa Grand Ballroom
Discussion panel: The Next "Big Plot": what new massive data collection campaign can transform tropical forest science?
In 1979 Steve Hubbell and Robin Foster set out to census all trees with a trunk diameter of 1 cm or larger in a 50-ha (1000 x 500 m) area in the center of Barro Colorado Island. This data collection effort, which became BCI's iconic 50-ha plot, was far more ambitious than any prior tree census. These initial data, subsequent repeat censuses, and complementary datasets collected on BCI and elsewhere have enabled new insights into population, community, and ecosystem ecology of tropical forests. The BCI 50-ha plot seeded what is now Smithsonian ForestGEO, a worldwide network of large-scale forest dynamics plots, and led transformative changes in how we approach tropical forest science. In this session, we ask, what is the next "big plot" equivalent – the next major data collection initiative that will have such a transformative effect? We start with a brief introduction by Stuart Davies, the director of Smithsonian ForestGEO. Then follow a series of short pitches for major new data collection initiatives on diverse topics. The panel and the audience will then discuss the strengths and weaknesses of alternative proposals, and how these and other efforts can advance understanding of tropical forests in the next century.

8:30 | Gamboa Grand Ballroom
Una conversación con Cristián Samper, Director General y Líder de Nature Solutions en el Bezos Earth Fund
Una conversación con Cristián Samper, Director General y Líder de Soluciones para la Naturaleza en el Bezos Earth Fund, quien será entrevistado por las Asociadas de Investigación de STRI Ximena Bernal (Universidad de Purdue) y Eloisa Lasso (Coiba-AIP). La experiencia de Samper en la dirección de organizaciones de conservación y biodiversidad de renombre, incluida STRI, servirá como base para una conversación vibrante sobre el futuro de la investigación científica sobre bosques tropicales y arrecifes que aborde los desafíos y oportunidades para financiar este trabajo.

10:15 | Gamboa Grand Ballroom
Sesión oral organizada: El potencial de las tecnologías modernas para avanzar en la investigación sobre los bosques tropicales
Los avances tecnológicos están permitiendo la recopilación y el análisis de conjuntos de datos cada vez más grandes y detallados sobre organismos y ecosistemas tropicales. Estos incluyen no solo avances en hardware, sino también avances en inteligencia artificial (IA). Aquí, los oradores presentan estudios de caso de cómo se están aplicando algunas de las tecnologías más prometedoras en la actualidad y discuten el potencial para obtener más información.

16:00 | Gamboa Grand Ballroom
Panel de discusión: La próxima "gran parcela": ¿qué nueva campaña de recopilación masiva de datos puede transformar la ciencia de los bosques tropicales?
En 1979, Steve Hubbell y Robin Foster se propusieron censar todos los árboles con un diámetro de tronco de 1 cm o más en un área de 50 hectáreas (1000 x 500 m) en el centro de la isla de Barro Colorado. Este esfuerzo de recopilación de datos, que se convirtió en la icónica parcela de 50 hectáreas de BCI, fue mucho más ambicioso que cualquier censo de árboles anterior. Estos datos iniciales, censos repetidos posteriores y conjuntos de datos complementarios recopilados en BCI y en otros lugares han permitido nuevos conocimientos sobre la ecología de la población, la comunidad y los ecosistemas de los bosques tropicales. La parcela de 50 hectáreas de BCI sembró lo que ahora es Smithsonian ForestGEO, una red mundial de parcelas de dinámica forestal a gran escala, y lideró cambios transformadores en la forma en que abordamos la ciencia de los bosques tropicales. En esta sesión, nos preguntamos, ¿cuál es el próximo equivalente de la "gran parcela", la próxima gran iniciativa de recopilación de datos que tendrá un efecto transformador? Comenzamos con una breve introducción de Stuart Davies, director de Smithsonian ForestGEO. A continuación, siga una serie de presentaciones breves sobre nuevas e importantes iniciativas de recopilación de datos sobre diversos temas. Luego, el panel y la audiencia discutirán las fortalezas y debilidades de las propuestas alternativas, y cómo estos y otros esfuerzos pueden avanzar en la comprensión de los bosques tropicales en el próximo siglo.

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Smithsonian
Tropical Research Institute

June | Junio 18

Abstracts
Resúmenes

June 18 • 9:00 • Gamboa Grand Ballroom

The ecology, evolution and conservation potential of anti-herbivore defenses in rainforest trees

Keynote presenter: Phyllis COLEY

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Phyllis COLEY[1,2]

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The ecological and evolutionary interplay between plants and the herbivores that consume them is a fundamental underpinning of both the origin and maintenance of diversity in tropical forests. I describe our results from the speciose tree genus, *Inga*, in Panama and four sites across the Amazona. I also address how this basic knowledge of defenses of young leaves created a bioprospecting project in Panama that enhanced scientific opportunities for researchers and students and promoted conservation.

June 18 • 10:30 • Gamboa Grand Ballroom

A century of bird studies on Barro Colorado Island

Presenter: W. Douglas ROBINSON

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W. Douglas ROBINSON

Oregon State University

Birds were among the organisms that first attracted scientists to BCI. Chapman, Van Tyne, Gross and others established a foundation for studies of tropical bird life histories, but BCI is most famous for the loss of bird species since its isolation. About 30% of the species richness initially reported by Chapman and others in the 1920s have disappeared and are still present on the nearby mainland just a few hundred meters away. The decline in richness took many decades and still continues albeit at a slower pace in the last two decades. Documenting extinctions was possible because ornithologists kept species lists covering most of the century. Since 1996, systematic surveys conducted with repeatable methods have also quantified numbers of birds at dozens of sites across the older and younger forests on BCI. Tests of hypotheses for the loss of bird species have centered on reduced reproductive success, possibly owing to mesopredator release, sensitivities of some understory species to potentially warmer and drier conditions on the island, and limited dispersal abilities of many tropical birds. The latter explains the long-term absence of otherwise regionally common species. Populations may decline and disappear on BCI for many reasons, including simple stochastic processes, but losses of species unwilling or unable to recolonize appear to be permanent. Understanding avian dynamics on BCI has also required better information on the regional avifauna, particularly the distributions of each species across the isthmian rainfall gradient, so the long-term BCI studies have also spurred greater knowledge of birds in central Panama.

June 18 • 10:45 • Gamboa Grand Ballroom

How tropical forest trees regenerate: Insights from long-term studies of flower and seed production and seedling dynamics

Presenter: S. Joseph WRIGHT

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S. Joseph WRIGHT, Osvaldo CALDERÓN, and Andrés HERNÁNDEZ

Smithsonian Tropical Research Institute

In the 1980s, SJW resolved to complete plant life cycles in BCI's 50-ha Forest Dynamics Plot, where Robin Foster and Steve Hubbell had recently tagged and identified 242,000 trees and shrubs larger than 1 cm in diameter at breast height. Today, we will present highlights from 38 years of weekly censuses of flower and seed production and 31 annual censuses of seedling dynamics. Highlights concern levels and causes of spatial, temporal, and interspecific variation in flower and seed production, seed dispersal, and seedling dynamics, and the consequences for plant regeneration and diversity. We explored interannual variation in the timing of flowering and potential climatic cues to establish that seasonal changes in incoming solar irradiance cue flowering for many BCI species. We used mapped locations of seed traps and potential seed-bearing trees to document broad interspecific variation in seed dispersal distances and widespread limitation of recruitment by failed seed arrival. We used mapped locations of seedling plots and neighboring plants to document strong conspecific negative density dependence for seedling survival for virtually all species, which becomes even stronger in wetter years and species with smaller seeds. We combined seed production and seedling dynamics to improve the representation of tree regeneration in an Earth system model. We added the dynamics of small saplings and plants larger than 1-cm DBH to complete life cycles and evaluate the cost of dioecy, lifetime relationships between morphological and demographic traits, and lifetime impacts of lianas on their tree hosts. Finally, we observed dramatic change in species composition, with lianas increasing in importance by 50%, and a strong community-wide increase in flower production from 1987 to 2004 followed by an equally dramatic decline in flower production between 2009 and 2024. There is much yet to learn, and we look forward to monitoring a full tree generation over BCI's second 100 years.

June 18 • 11:00 • Gamboa Grand Ballroom

Insights from the understory: Long-term monitoring of seedlings in the Barro Colorado Island 50-ha Forest Dynamics Plot

Presenter: Liza S. COMITA

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Liza S. COMITA[1,2], Nohemi HUANCA-NUÑEZ[1], Salomón AGUILAR[2], Stephen HUBBELL[2,3], and Rolando PÉREZ[2]

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Dynamics at early life stages play a critical role in shaping the composition and diversity of tropical tree communities. To better understand spatial and temporal patterns of recruitment, growth, and survival at early life stages, in 2001 we established a long-term census of woody seedlings and small saplings in the BCI 50-ha Forest Dynamics Plot. Individuals ≥20 cm tall and <1cm diameter at 1.3m (dbh) were censused in ca. 20,000 1-m2 seedling plots every 1-2 years between 2001 and 2018, resulting in a dataset of >1M observations of >400 tree, shrub, and liana species. Analyses of this long-term dataset have provided novel insights into the regeneration ecology of tropical plant species. In particular, I will discuss what we have learned about differences among tropical tree species in their response to spatial and temporal variation in water availability and in their sensitivity to conspecific neighbor density, as well as the implications of these findings for our understanding of how high levels of diversity are maintained in tropical forests.

June 18 • 11:15 • Gamboa Grand Ballroom

Insights into tropical forest nutrient limitation from a factorial nitrogen, phosphorus, and potassium addition experiment in an old-growth forest

Presenter: Joseph B. YAVITT

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Joseph B. YAVITT[1] and S. Joseph WRIGHT[2]

1. Cornell University. 2. Smithsonian Tropical Research Institute

We initiated a replicated, factorial nitrogen-phosphorus-potassium addition experiment in old-growth forest growing on a highly weathered soil (Oxisol) on Gigante Peninsula in 1998. Our aim was to determine which, if any, of these nutrients limit productivity and other ecosystem functions, and to study how trees maintain high level of productivity despite an impoverished soil. Here we synthesize responses through 24 years of annual nutrient additions. The experiment provides clear evidence that nutrient availability impacts multiple ecosystem components. All three nutrients limit tissue nutrient concentrations, allocation to roots, and seedling growth. Phosphorus also limits soil microbial biomass, stand-level fine litter productivity, reproductive effort by trees, and soil and litter invertebrate abundance. Potassium also limits stomatal function and soil and litter invertebrate abundance. The experiment provides no evidence for soil eutrophication, as the amount of soil organic matter declined during the study period. Going forward, we anticipate additional lagged responses by long-lived tree species adapted to infertile soil and a shift in tree species composition to species adapted to more fertile soils. How soil carbon will respond is still uncertain.

June 18 • 11:30 • Gamboa Grand Ballroom

Long-term monitoring on Barro Colorado Island suggests the value of small conservation preserves for tropical insects

Presenter: Greg LAMARRE

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Greg LAMARRE[1,2], and Yves BASSET[1,2,3,4]

1. Biology Centre of the Czech Academy of Sciences, Institute of Entomology, Ceske Budejovice. 2. Smithsonian Tropical Research Institute. 3. Faculty of Science, University of South Bohemia, Ceske Budejovice. 4. Maestria de Entomologia, Universidad de Panamá

Ongoing declines in insect biodiversity due to various anthropogenic factors threaten to destabilize ecosystems worldwide. Understanding the causes and consequences of insect declines has become an important goal in ecology, particularly in the tropics, where most of terrestrial diversity occurs. Since 2009, the STRI Arthropod Program has systematically monitored 23 focal arthropod taxa on BCI, providing crucial data for assessing temporal variation and long-term trends. Here, we examine long-term population trends for some common insect taxa and especially for the butterfly community and its six most common species on BCI. Total abundance of all species combined increased significantly over time, as did the abundances of four of six common species. This is in line with previous findings for insect populations on BCI and strongly contrasts with the sharp declines observed in other temperate and tropical locations. We briefly review potential explanations for the (so far) lack of decline of insect populations on BCI. We emphasize the value of BCI as a conservation preserve for protecting insect populations.

June 18 • 11:45 • Gamboa Grand Ballroom

Panamabiota.org: An ever-growing resource of information on Panamanian species

Presenter: Edward E. GILBERT

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Edward GILBERT, Samanta ORELLANA, and Nico FRANZ

Arizona State University

The Panama Biodiversity portal, initially developed in 2015 through a partnership between the Smithsonian Tropical Research Institute (STRI) and Arizona State University (ASU), began with the modest aim of showcasing vertebrate collections managed by STRI. Over time, collaborative efforts have expanded its scope, now encompassing diverse organismal groups and datasets from over 20 institutions.
The portal provides a comprehensive array of data, including species inventories, taxonomic descriptions, field images, taxonomic authoritative references, and morphological trait data.
Panamabiota was established using Symbiota (http://symbiota.org), an open-source software specifically designed for managing, mobilizing, and integrating biodiversity data. Symbiota provides a framework that facilitates selective import of distributed datasets into a unified data store with built-in infrastructure to enable regular synchronization of the local data cache with the data source. The software additionally serves as a content management system providing the means to collaboratively manage any dataset directly through the portal interface. Symbiota has broad community support including partnerships with both the NEON and iDigBio NSF-funded projects with active development coordinated through a network of GitHub code repositories.
The purpose of Panamabiota is to provide an integrated data store in support of scientific research, while also establishing an information-rich framework that allows the general public to explore the Panamanian biodiversity. In order to reach the portal's full potential, the project seeks to establish broader collaborations within the greater research community throughout Panama with the ultimate goal of establishing a community-driven data portal that is collaboratively managed by a collective of taxonomic experts.

June 18 • 11:55 • Gamboa Grand Ballroom

The Smithsonian Tropical Data Portal – Helping people preserve, share, and discover tropical data and knowledge

Presenter: Helene C. MULLER-LANDAU

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Helene C. MULLER-LANDAU

Smithsonian Tropical Research Institute

Scientists working at Barro Colorado Island over the last 100 years have collected a wealth of biological and environmental data that have contributed to our knowledge of tropical organisms and ecosystems. These data are of enduring value and usefulness, including for syntheses, meta-analyses, and as points of comparison as we seek to understand how tropical forests are being altered by anthropogenic global change. However, many of BCI's historically important datasets were collected at a time when data publication was not common, are currently inaccessible, and are in danger of being lost forever. BCI is unfortunately typical in this respect; only a small minority of tropical datasets are available in public archives for discovery and reuse. Further, many tropical scientists and students lack training in best practices for data management and reproducible research, practices that are important for the preparation of high-quality data publications. The Smithsonian Tropical Data Portal and associated efforts aim to address these challenges and help the international community preserve, share, and discover tropical data and other research products including protocols, code, reports, and presentations. We aim to help make past, current, and future tropical datasets accessible by providing resources for documentation, management, storage, and visualization of tropical research data. BCI alumni, STRI researchers, and scientists and students working in the tropics more generally are all welcome to use the Smithsonian Tropical Data Portal. Seed funding for this new initiative is provided by a gift from Dr. Stephen Quake and the Wallace Line Fund.

June 18 • 13:30 • Gamboa Grand Ballroom

Biogeographic assembly of BCI's tree community — Insights from widespread tree species

Presenter: Chris DICK

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Jordan BEMMELS[1,3], Álvaro Pérez[4], Renato VALENCIA[4], and Chris DICK[1,2]

1. University of Michigan. 2. Smithsonian Tropical Research Institute. 3. University of Victoria. 4. Pontificia Universidad Católica del Ecuador (PUCE)

BCI's tree flora is a model system for community ecology, but how did it assemble, and how is it similar or different from other Neotropical tree communities? In our research we have focused on the widespread species in the BCI tree community, and in particular those whose geographic ranges extend in to the Amazon basin. In this talk we will discuss the traits common to widespread Neotropical tree species, their estimated ages and dispersal histories, and their patterns of genetic diversity. We'll present recently published results of a study of the genetic diversity of 49 tree species that we sampled in the ForestGEO plots in BCI and Yasuní, Ecuador.

June 18 • 13:45 • Gamboa Grand Ballroom

The Limbo long-term bird project: Lessons from the past 47 years and future directions

Presenter: Kimberley C. JORDAN

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Kimberley C. JORDAN[1], Jeffrey D. BRAWN[2], Rebecca C. WILCOX[1,3], Henry S. POLLOCK[4], T.J. BENSON[2], Reina GALVAN[1], and Corey E. TARWATER[1,5]

1. University of Wyoming. 2. University of Illinois Urbana-Champaign. 3. California Academy of the Sciences. 4. Southern Plains Land Trust. 5. Smithsonian Tropical Research Institute

Long-term data is vital for understanding how temporally variable environments influence populations and communities and for understanding the ongoing effects of global change. Nevertheless, long-term data is challenging to collect and to fund. On the Limbo Plot, located on Pipeline Road in Soberania National Park, we manage the longest running demography study of birds in the Neotropics (1977 – current). Utilizing this mist-netting data, we have learned that the vital rates of bird species are responsive to abiotic factors and that species vary in their responses. Further, we have found that even in this protected forest, 70% of bird species have declined in abundance, primarily due to increases in temperature. Body condition of most birds has declined over time, while structural size has remained the same. We are now investigating how habitat heterogeneity, based on Lidar data, impacts diversity and abundance of different types of species and causes of variation in population demography. We are currently working with people with long-term data across the Neotropics to compare across sites and understand broader scale changes in lowland tropical bird communities. While the original purpose of the study was to first describe lowland tropical bird communities, the focus has now shifted to understanding the abiotic factors that are driving changes in populations, and identifying which species may be more or less resilient to changes in climate.

June 18 • 14:00 • Gamboa Grand Ballroom

Seed-fungal interactions: Lessons from BCI research and a few perspectives

Presenter: Paul-Camilo ZALAMEA

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Paul-Camilo Zalamea[1,2], Carolina Sarmiento[1,2], A. Elizabeth Arnold[3,4], and James W. Dalling[5,2]

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Mechanisms that maintain plant diversity at local and regional scales have long captured the interest of ecologists. Recently, the role of plant-microbe interactions in structuring the composition of plant communities has become apparent. Early studies focused on antagonism, showing that fungi and fungus-like pathogens promote plant diversity by imposing density- and distance-dependent mortality on seedlings and saplings. However, an emerging perspective is that non-pathogenic fungi also define plant health, with implications for shaping plant community structure. Focusing on seeds, a key component of fitness for most tropical trees, and seed-infecting fungi, this talk centers around three main findings of our BCI research: 1. Although host-generalists are common, host species identity is the primary determinant of fungal community composition in seeds of tropical pioneer trees. This host-differentiation of fungal communities and susceptibility to fungal infection is strong even among phylogenetically closely related species. 2. Interspecific variation in seed survival does not necessarily reflect escape from fungal infection. Even decades-old viable seeds recovered from the soil seed bank were frequently infected by fungi. 3. Seed-endophytic communities (i.e., the community of fungi able to infect internal seed tissues) of individual seeds are often characterized by low species richness. Culture-based and culture-free approaches show that seed interiors of individual seeds only harbor one or very few species of fungi, making seeds ideal models to study priority effects in ecological studies. To conclude, we will discuss new research endeavors to better understand seed-fungal interactions on larger geographical and environmental scales.

June 18 • 14:15 • Gamboa Grand Ballroom

Increasing liana abundance in tropical forests: Patterns, causes, & consequences

Presenter: Stefan A. SCHNITZER

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Stefan A. SCHNITZER[1,2]

1. Marquette University. 2. Smithsonian Tropical Research Institute

Liana abundance (density and biomass) has increased in tropical forests around the world, including the forests of the BCNM. Annual liana density increases have ranged between 1% and 4.3% per year. The increase in lianas is alarming because lianas influence many aspects of tropical forest diversity and functioning; thus, understanding the patterns, causes, and consequences of increasing lianas is critical for predicting how tropical forests will change in the near and distant future. Here, I present evidence for the general pattern of increasing liana abundance in tropical forests, including my own laboratory's long-term data from central Panama (BCI and Gigante Peninsula). I confront the hypothesized factors thought to be responsible for increasing liana abundance with empirical data and propose the likely explanations. I then present experimental findings on the possible effects of lianas on tree community composition and diversity, as well as evidence for the ability of liana populations and communities to limit their own abundance.

June 18 • 14:30 • Gamboa Grand Ballroom

The past, present and future of bat research on Barro Colorado Island, and beyond

Presenter: Rachel PAGE

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Rachel PAGE

Smithsonian Tropical Research Institute

From early natural history observations on bats by Thomas Barbour, Emmett Reid Dunn, and Frank Chapman in the 1930's, to echolocation recordings by Donald Griffin in the 1950's, to electrophysiology by Alan Grinnell in the 1960's, radiotracking by Douglas Morrison and mistnetting surveys by Frank Bonaccorso, Don Wilson, Alfred Gardner, and Charles Handley in the 1970's, Barro Colorado Island (BCI) has been a mecca for tropical bat research for nearly a century. With her seminal work beginning in the 1990's, Elisabeth Kalko positioned BCI as a center for the study of ecology and niche partitioning in bats, leading to a myriad of studies investigating how the distinct sensory abilities, foraging behaviors, and roosting habits of different bat species allow for species coexistence. Since, numerous researchers have contributed to our current understanding, establishing BCI and its surrounding areas as the best studied bat communities in the Neotropics. Current research builds on this strong foundation, combining detailed natural history observations with empirical tests and onboard recording and tracking in nature. As technology becomes ever smaller, cheaper, and more accessible, and omics approaches become increasingly widespread, new doors are opening to an ever-deepening understanding of the bats of BCI and beyond.

June 18 • 14:45 • Gamboa Grand Ballroom

BCI and the ever-expanding legacy of Stan Rand

Presenter: Michael J. RYAN

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Michael J RYAN[1,2]

1. University of Texas, Austin. 2. Smithsonian Tropical Research Institute

An institution's greatness is defined in part by its physical facilities, and BCI is the crown jewel of STRI. But equally important is its humanity — and during his time Stan Rand was perhaps STRI's greatest resource after BCI. In this brief talk I discuss some of Stan's pioneering work on frog communication (only one of Stan's several research foci) and a highlight how that research program expanded in both breadth and depth in what is his ever-growing legacy.

June 18 • 16:00 • Gamboa Grand Ballroom

Vegetation of BCI during the Last Glacial Maximum

Presenter: Carlos JARAMILLO

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Carlos JARAMILLO[1], and Luciano VARELA[2]

1. Smithsonian Tropical Research Institute. 2. Universidad de la República, Montevideo, Uruguay

About 180-200 generations have passed for the long-lived species of tropical trees in BCI since the Last Glacial Maximum (LGM). This is a short time interval compared to a species' longevity, which ranges in the hundreds of thousands to a few million years, and yet, Earth's climatic conditions were much different compared to today. Mean annual temperature was ~5 C° cooler and CO^2 concentration was ~180 ppm, 100 ppm lower than preindustrial values and 240 ppm lower than the year 2024. There are no empirical estimates for precipitation at BCI for the LGM, although most studies assume the region was much drier. We reviewed all the available empirical and model-based biome predictions for BCI during the LGM and found massive differences. From models that predict a rainforest-like that occurring today, probably with less canopy cover, to those predicting a full transformation into open environments like grasslands. Nevertheless, most models suggest a massive transformation of BCI only a few thousand years ago that seems to be in contradiction with vegetation genetic data. Furthermore, it is still uncertain the role of biome changes in the animal dispersals along the Americas during the Great American Biotic Interchange. In short, we need to understand the BCI's deep past if we want to predict its future.

June 18 • 16:10 • Gamboa Grand Ballroom

Four centuries of human presence before the forests: Barro Colorado and the Transisthmian zone in the Early Modern Period

Presenter: Tomás MENDIZÁBAL

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Tomás MENDIZÁBAL[1,2,5], Stewart REDWOOD[3], Warwick BRAY[4], and Richard COOKE[2,5]

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Despite Barro Colorado Island's contemporary image as an island and as an untouched tropical forest wilderness, we aim to present archival and cartographical evidence that reminds us this pristine image is a product of only the last century of site use. Prior to the American government's expulsion order of 1912 and dating back to the early 16th century following the Spanish invasion of Panama (and the native depopulation), Barro Colorado became part of the densely populated, highly modified and intensely traveled region known by historians as the "Strategic Triangle." Positioned along the Camino de Cruces, one of the isthmus's two main traffic arteries, it connected Spain with its South American colonies and, eventually, the entire world as the direct precursor to the Panama Railroad and later the Panama Canal. The Chagres River, flowing alongside Barro Colorado, transported much of the wealth, goods, and people that sustained the Spanish Empire. The riverbanks from Cruces (near today's Gamboa) to the Caribbean Sea were dotted with hamlets and plantations, accommodating up to 10% of the isthmus's population by the early 20th century. These settlements played a crucial role in producing agricultural goods that fed the immediate countryside, the terminal cities of the crossing, and the thousands of travelers passing through. This four-century-long process of human land management, immersed in the wider context of the early globalization of the world, abruptly ceased with the establishment of the Canal Zone, returning the site to a human-free situation not seen for 15,000 years.

June 18 • 16:20 • Gamboa Grand Ballroom

The landscape history of Barro Colorado and Gamboa: Remembering the old towns of Gorgona and Cruces

Presenter: Marixa LASSO

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Marixa LASSO

CIHAC AIP, SNI, STRI

This talk examines the history of the landscape around Barro Colorado and Gamboa, what used to be the towns of Gorgona and Cruces and their hinterland. It examines the urban life in those towns and the agricultural practices around them. It argues that this area was the central hub of the Old-Cruces road and the Chagres waterway, and that this strategic location led to a rich agricultural, urban and political life. Finally, the presentation will briefly examine the process of depopulation that allowed the construction of the current landscape.

June 18 • 16:30 • Gamboa Grand Ballroom

The Gigante Litter Manipulation exPeriment (GLiMP)

Presenter: Edmund V. J. TANNER

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Edmund V. J. TANNER[1, 6], Chadtip RODTASSANA[2], Laëtitia M. BRÉCHET[3,4], Andrea G. VINCENT[5], Sara LEITMAN[1], S. Joseph WRIGHT[6], and Emma J. SAYER[7]

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The Gigante Litter Manipulation Project (GLiMP) was established in 2000 to investigate the contribution to productivity made by nutrients in litterfall. Soil nitrate and nitrogen (N) concentrations in roots and leaves decreased quickly and significantly with litter removal (LR) and increased quickly and significantly with litter addition (LA). In contrast, phosphorus (P) concentrations in soil and plant tissues did not differ significantly between treatments and controls, but they were mostly higher in LA than LR treatments. Productivity responses developed more slowly. The LR treatment reduced trunk growth by 26%, litterfall production by 20%, and fine root mass by 20% and production by 7%, with effects becoming evident after 10 years of litter manipulation. The LA treatment increased litterfall by 11% in years 6–17 but did not significantly affect trunk growth or roots. The LR treatment reduced above- and belowground productivity, and the LA treatment increased one component of aboveground productivity. We hypothesize that N limitation is responsible for reduced productivity after litter removal.

June 18 • 16:40 • Gamboa Grand Ballroom

Herbivory constrains symbiotic nitrogen-fixing trees via density-dependent effects

Presenter: Sarah A. BATTERMAN

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Sarah A. BATTERMAN[1,2,3], William R. BARKER[2], Oliver PHILLIPS, and Liza COMITA[3,4]

1. Cary Institute of Ecosystem Studies. 2. University of Leeds. 3. Smithsonian Tropical Research Institute. 4. Yale University.

A growing body of evidence suggests that periods of nitrogen limitation in tropical forests are more common than previously predicted, and that nitrogen-fixing trees can enhance forest growth when soil nitrogen is limiting. A recent observation of a high herbivory cost for fixers raises the question of whether herbivory affects demography of fixer seedlings and ultimately constrains their abundance in tropical forests. In this talk, we will examine the growth, survival and strength of negative conspecific density-dependent effects for >37,000 fixer and non-fixer seedlings monitored in seedling plots on Barro Colorado Island from 2001 to 2014. Fixer seedlings had higher survival than non-fixers at very low densities, but they suffered greater conspecific density-dependent effects on survival and had lower survival rates than non-fixers at densities above 2 seedlings m-2. Fixers also had higher conspecific density-dependent effects on growth than non-fixers, whereby fixer growth was lower than non-fixers at densities above 5 seedlings m-2. Across a subset of 250 seedlings, herbivory was a contributor to negative density-dependent effects for fixers – herbivory increased with seedling densities for fixers but not non-fixers, and led to lower growth rates at higher herbivory. Our findings suggest that the benefits of fixation lead to higher survival for fixer seedlings at very low densities, but that herbivory contributes to a significant cost that prevents fixers from succeeding at higher densities and therefore may constrain fixation in tropical forests.

June 18 • 16:50 • Gamboa Grand Ballroom

Barro Colorado Island: is flora and its role in the study of Araceae

Presenter: Thomas CROAT

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Thomas CROAT

Missouri Botanical Garden

In 1967, the modern Flora of Barro Colorado Island was begun with two years of fieldwork during which time I made collections and observations during every month of the calendar year. It resulted in a complex flora with identification keys, a key to sterile woody plants capable of serving the needs of ecologists and animal behaviorists, and phenological studies that reported flowering and fruiting sequences. Equally important to science was that it launched a 50 year-long study of the family Araceae which has resulted in the collection of nearly 110,000 specimens world-wide, and the discovery and naming of more than 3,400 new species in Central and South America.

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100 years of discoveries in termite science on and around BCI, and more to come

Presenter: Yves ROISIN

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Yves ROISIN

Université Libre de Bruxelles, Belgium

During the early years of the Panama Railroad, the appetite of termites for wooden buildings and railway sleepers prompted engineers to carry out the first detailed observations on termites across the isthmus. The first descriptions of Panamanian termites by Nathan Banks date back to 1918, but it is in 1924 that both Banks and renowned termite specialist Thomas E. Snyder launched termite studies from the brand new BCI station. In the following years, Snyder described almost all termite species presently known from Central Panama. However, he largely neglected the soldierless *Anoplotermes*-group, workers alone providing few diagnostic characters at that time. Apart from a gloomy chapter of insecticide testing (1943–1954), BCI termites were then mostly left in peace until the late 1970s, when the development of sociobiology triggered a new wave of research on colony dynamics, castes and reproduction, for which Barbara Thorne, Eldridge Adams and myself successively found a home on BCI. In 2003–2004, BCI served as a base for the IBISCA project, during which the San Lorenzo Protected Area forest was screened for multiple arthropod taxa from the soil to the canopy, yielding original data on the vertical distribution of termites in a rainforest. Since 2009, BCI termites have been included in the ForestGEO long-term arthropod monitoring program. Today, the taxonomy of the *Anoplotermes*-group throughout the Neotropics is progressing rapidly, thanks to robust diagnostic characters from worker gut anatomy and DNA sequencing. Several new species in collections from BCNM and its surroundings are awaiting description, whereas recent as well as historical samples are now being incorporated into a broad collaborative effort to resolve the phylogeny and zoogeographical history of termites worldwide.

June 18 • 17:10 • Gamboa Grand Ballroom

Green iguanas and the recognition of reptile sociality

Presenter: Gordon M. BURGHARDT

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Gordon M. BURGHARDT[1] and Brian C. BOCK[2]

1. University of Tennessee. 2. Universidad de Antioquia

A. Stanley Rand's study of female iguana communal nesting behavior on the islet Slothia, off of BCI, ushered in a series of studies and publications that, in retrospect, changed our understanding of social behavior in squamate reptiles. Slothia was a convenient accessible site where observations and filming could occur unobtrusively. Many aspects of lizard behavior were observed there for the first time, and while many have been corroborated by subsequent studies, other behaviors have not been replicated, primarily because continual observation has not been implemented elsewhere. The first reported observations of the behavior of emerging and hatchling iguanas suggested a level of social affiliative behavior never before recorded that was previously considered inconceivable in reptiles. Their social behavior was shown to continue after the hatchlings migrated to BCI, with important fitness consequences. Subsequent studies supported by STRI on the Panamanian islands of Flamenco and San Jose, as well as on several ranches in the Venezuelan Llanos, documented details of courtship, mating, communication, diet, and other aspects of their behavior, which led to a 1981 symposium and subsequent book edited by Stan and Gordon Burghardt in 1982. Four decades later another volume appeared, The Secret Social Lives of Reptiles (Doody, Dinets, & Burghardt, 2021) that for the first time brought together studies on non-avian reptile sociality, almost all of it gathered since the pioneering BCI studies. Stan Rand led many important research projects on BCI dealing with amphibians and reptiles, but fostering the iguana work is one of his major legacies.

BARRO COLORADO ISLAND 100 YEARS

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Barro Colorado Island long-term environmental monitoring program

Presenter: Steven PATON

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Steven PATON, Sergio DOS SANTOS, Brian HARVEY, and Raúl RIOS

Smithsonian Tropical Research Institute

In addition to being one of the best and longest studied tropical forests, Barro Colorado Island (BCI) also has one of the best and longest duration environmental monitoring records. Beginning in 1925 with data collected by the then Panama Canal Company, BCI has over 98 years of unbroken precipitation data. Beginning in 1972 as part of the Terrestrial Environmental Sciences Program (T-ESP), a much more extensive monitoring program was established on the island. This program, now known as the Physical Monitoring Program, includes monitoring at 4 locations (the laboratory clearing, Lutz watershed, AVA tower, and Conrad stream). The program monitors a suite of meteorological and hydrological parameters including precipitation, temperature, humidity, wind, soil moisture and runoff. These data have been instrumental in helping researchers investigate how environmental conditions affect biological systems on the island from the scale of minutes to decades. All data are freely available on the program's website https://biogeodb.stri.si.edu/physical_monitoring/

P2

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Lutz Creek and Conrad Trail Stream hydrology, Barro Colorado Island; Two leaky catchments

Presenter: Robert F. STALLARD

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Robert F. STALLARD[1,2] and Steven PATON[1]

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With 50 years of exceptional hydrologic data on Lutz Creek and 28 years on the Conrad Trail Stream, we find the following. Average rainfall (1994-2020) is 2,661 mm for the lab clearing on BCI. Runoff for Lutz is 1,001 mm and Conrad is 647. If we assume an evapotranspiration of 1,307 mm based on a canopy-top Bellani-plate atmometer, then to close the water budget, there must be 342 mm of groundwater loss from the Lutz catchment and 707 mm of groundwater loss from the Conrad catchment. The annual rainfall from the Lab Clearing correlates strongly with annual runoff from both catchments. The linear relationship intercepts the rainfall axis at about 1,350 mm, which is also close to the estimated evapotranspiration. A year with rainfall having about 350 mm less than the driest year of the last 100 years, 1997 at 1,699 mm, would dry up both Lutz Creek and the Conrad Trail stream. This is a conceivable outcome of future of climate variability having wetter wet years and drier dry years than any in the last 100 years.

P3

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Soils of Barro Colorado Island

Presenter: Joseph B. YAVITT

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Joseph B. YAVITT

Cornell University

Soils on Barro Colorado Island (BCI) are described using formal soil survey. More than 750 observations are grouped into six soil forms: shallow stony fine loams, dark fine loams, gleys, heavy clays, pale-swelling clays, and red-light clays. Only the red-light clays are restricted to a tropical climate and are the characteristic deep, highly weathered, nutrient-depleted, acidic soils of the tropics. The other soil forms are less weathered, which is consistent with ongoing regional uplift and erosion despite the tropical climate. Less weathering is associated with poor drainage (gleys, heavy clay soils), chemical element retention (pale-swelling clay soils), and soil erosion removing the most weathered surface material on the steeper surfaces (shallow stony fine loams). BCI has a broad range of soils with different degrees of development, drainage, nutrient fertility, and capacity to store soil organic matter. Soil survey and soil classification are ongoing processes and refinement with more work is expected.

P4

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Panamabiota.org: an ever-growing resource of information on Panamanian species

Presenter: Edward E. GILBERT

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The Panama Biodiversity portal, initially developed in 2015 through a partnership between the Smithsonian Tropical Research Institute (STRI) and Arizona State University (ASU), began with the modest aim of showcasing vertebrate collections managed by STRI. Over time, collaborative efforts have expanded its scope, now encompassing diverse organismal groups and datasets from over 20 institutions.
The portal provides a comprehensive array of data, including species inventories, taxonomic descriptions, field images, taxonomic authoritative references, and morphological trait data.
Panamabiota was established using Symbiota (http://symbiota.org), an open-source software specifically designed for managing, mobilizing, and integrating biodiversity data. Symbiota provides a framework that facilitates selective import of distributed datasets into a unified data store with built-in infrastructure to enable regular synchronization of the local data cache with the data source. The software additionally serves as a content management system providing the means to collaboratively manage any dataset directly through the portal interface. Symbiota has broad community support including partnerships with both the NEON and iDigBio NSF-funded projects with active development coordinated through a network of GitHub code repositories.
The purpose of Panamabiota is to provide an integrated data store in support of scientific research, while also establishing an information-rich framework that allows the general public to explore the Panamanian biodiversity. In order to reach the portal's full potential, the project seeks to establish broader collaborations within the greater research community throughout Panama with the ultimate goal of establishing a community-driven data portal that is collaboratively managed by a collective of taxonomic experts.

P5

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Tree damage as an ecological process: Evidence from a pantropical monitoring program

Presenter: David MITRE

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Forests are key to mitigate climate change. However, large uncertainties remain on how these ecosystems will respond to future environmental changes, especially in the tropics, where the high species diversity imply different responses to a particular stressor. Here we present evidence of a key, but an underappreciated, ecological process in the dynamics of tropical forests: tree damage. We use observations from 29 annual mortality and damage censuses across seven tropical forest plots of the ForestGEO network, including the 50-ha forest dynamics plot in Barro Colorado Island in Panama, to study the role that damage to living trees has on forest dynamics. We show that tree damage was one of the most important mortality risk factors and contributes to a substantial, yet rarely quantified, proportion of total AGB losses. We also show that conventional forest inventories ignoring tree damage (1) overestimate stand-level aboveground biomass (AGB) stocks by 4% (1-17% range across forests) because assume structurally complete trees, (2) underestimate total AGB loss by 29% (6-57% range across forests) due to overlooked damage-related AGB losses, and (3) overestimate AGB loss via mortality by 22% (7-80% range across forests) because of the assumption that trees are undamaged before dying. Damage on living trees is likely to become more important as the frequency and severity of forest disturbances increase.

P6

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The Central Panama drone datasets: A resource for studies of forest structure, dynamics, and phenology

Presenter: Vicente VASQUEZ

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Vicente VASQUEZ, Juan Camilo OSORIO, Milton GARCIA, Melvin HERNANDEZ, Pablo RAMOS, Paulino VILLARREAL, and Helene C. MULLER-LANDAU

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Camera-carrying drones can survey forest canopies at high spatial resolution, high temporal frequency, large spatial extent, and low cost. Since 2014, the Muller-Landau Lab has collected and published drone imagery (RGB) for Barro Colorado Island (BCI) and multiple other sites in central Panama (links at https://hmullerlandau.com/). Here, we describe the methods used, present an overview of the available datasets, and briefly summarize associated research. Each set of drone photos is processed with photogrammetry software to produce a color orthomosaic image , a 3D point cloud for the top of the canopy, a canopy surface elevation mode, and where possible, a canopy height model. Repeat datasets for the same site are horizontally and vertically aligned to enable time series analyses. Within mapped plots, we conducted field work to link tree crowns visible in the imagery to tagged trees, and thereby associate census data including tree species identity and trunk diameter. Crown maps were refined to more exactly capture crown boundaries using AI tree detection and segmentation algorithms. The largest time series is the BCI 50-ha plot 4-cm resolution aerial photogrammetry data, which starts in October 2014, and continues to the present, with monthly resolution through 2022, and weekly resolution since 2023. The largest spatial extent is the whole-BCI dataset, (1450 ha), with data for 2015, annually from 2018 to 2022, and multiple times per year since 2023. In addition, there is one-time or repeat imagery for many other Smithsonian sites in central Panama, including the San Lorenzo (Sherman) 6-ha plot and crane site, the Parque Natural Metropolitano crane site, the Gigante fertilization plot, areas in Agua Salud, and numerous 1-ha ForestGEO plots. To date, these datasets have been used in publications on leafing and flowering phenology of individual tree species, and on temporal and spatial variation in canopy disturbances.

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Insights and opportunities associated with the Smithsonian ForestGEO small plots in Central Panama

Presenter: Helene C. MULLER-LANDAU

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Helene C. MULLER-LANDAU[1], Camille PIPONIOT[2], Rolando PEREZ[1], Salomon AGUILAR[1], Suzanne LAO[1], David MITRE[1], Juan Camilo OSORIO[1], and Richard CONDIT[3]

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Comparisons among sites varying in climate and soils can yield important insights into the mechanisms shaping forest carbon stocks and fluxes. Research at a network of small plots spanning regional variation in Central Panama including a strong regional rainfall gradient and high geological heterogeneity provides excellent opportunities for such comparisons, and places findings for Barro Colorado Island (BCI) in a broader context. Here, we first examine regional variation in climate, soils, and land use history. We then present analyses of among-plot variation in aboveground biomass (AGB), aboveground woody productivity (AWP), and tree mortality rates in relation to dry season severity and soil fertility. We enumerate the different types of complementary datasets that have been collected in subsets of these plots, which offer opportunities to investigate alternative hypotheses regarding underlying mechanisms, and close with a discussion of promising directions for future research.

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Variation in forest structure, dynamics, and composition across 108 ha of large forest plots on Barro Colorado Island

Presenter: Victoria MEAKEM

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The 50-ha plot on Barro Colorado Island (BCI) has been extensively studied and has served as an important model for tropical forest ecology. However, this plot represents only a small amount of the topographic diversity that exists on the island, which may have important consequences for variables such as tree mortality and biomass productivity. We examined 58 ha of other large (≥6 ha) mapped forest plots censused for trees ≥20 cm in trunk diameter in 2004 and 2014, as well as several smaller plots, to assess the relationship between topography and biomass, and to explore the effects of topographies underrepresented by the 50-ha plot. Specifically, we examined the impacts of elevation, slope, geology, and forest age on aboveground biomass, above-ground woody productivity, mortality rate, basal area, and tree species composition. While the 50-ha plot is located entirely on the Upper Igneous Unit geological formation and mostly in old-growth forest, the other large plots include 37 ha in old secondary forest, and 11 ha on the Bohio Volcanic geological formation. Across the large plots, aboveground biomass and aboveground woody productivity were higher in old growth than secondary forest, and tree mortality rates were higher on the Upper Igneous Unit than on other geological formations. Tree species composition varied significantly but modestly with forest age and geology. These large plots represent an important resource for scientists working on BCI and should be maintained and expanded to capture additional landscape-level variation.

P9

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Long-term studies on liana ecology on BCI, Gigante Peninsula, & across the isthmus of Panama

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Lianas are an important component of tropical forests and research on the lianas of the Barro Colorado Nature Monument and across the isthmus of Panama has helped to elucidate their diversity, distribution, natural history, ecology, and role in tropical forests. Over the past two decades, we have been following more than 125,000 lianas in multiple large scale, long-term, studies and experiments on BCI, the Gigante Peninsula, and in small plots across the isthmus of Panama. In the BCI 50-ha plot, we have conducted censuses of the lianas (≥1 cm diameter) in 2007 and 2017, leading to a more complete understanding of the ecology of lianas and their changes over time. On Gigante Peninsula, we have followed the response of trees and tropical forest processes to liana removal in eight 80x80 m plots, as well as in eight same-sized control plots. We established the liana removal study in 2008 and all lianas were removed in 2011 and have been kept liana free ever since. We are also following the lianas in 24 small (1 ha) plots across the isthmus of Panama to test hypotheses on the mechanisms that control plant distributions across environmental gradients. These long-term studies and experiments have led to a greater understanding of the ecology of lianas with respect to their response to environmental conditions as well as their myriad effects on the environment.

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Thirty years of pollen rain sampling in the BCI 50-ha plot

Presenter: J. Enrique MORENO

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Pollen production and dispersal is critical to plant reproduction yet remains poorly understood in tropical forests. To address this knowledge gap, we are conducting a long-term pollen trapping study in the BCI 50-ha plot, a study that begin in 1991 and continues to this day. Pollen samples from twenty traps on the forest floor are collected annually, processed, and identified to species, providing a 30-year record of pollen rain. The setting is ideal because location of the traps within a large-mapped plot provides information on the sizes and identities of all the trees surrounding the traps, and pollen morphologies of all BCI plant species are well known. Here we describe our methods, review published studies, and present new results on interannual variation in pollen rain in this dataset. We close with discussion of the many possibilities for future research enabled by these data.

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Variability within the 10-year pollen rain of a seasonal Neotropical forest and its implications for paleoenvironmental and phenological research

Presenter: J. Enrique MORENO

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Tropical paleoecologists use a combination of mud-water interface and modern pollen rain samples (local samples of airborne pollen) to interpret compositional changes within fossil pollen records. Taxonomic similarities between the composition of modern assemblages and fossil samples are the basis of reconstructing paleoclimates and paleoenvironments. Surface sediment samples reflect a time-averaged accumulation of pollen spanning several years or more. Due to experimental constraints, modern pollen rain samples are generally collected over shorter timeframes (1–3 years) and are therefore less likely to capture the full range of natural variability in pollen rain composition and abundance. This potentially biases paleoenvironmental interpretations based on modern pollen rain transfer functions. To determine the degree to which short-term environmental change affects the composition of the aerial pollen flux of Neotropical forests, we sampled ten years of the seasonal pollen rain from Barro Colorado Island, Panama and compared it to climatic and environmental data over the same ten-year span. We establish that the pollen rain effectively captured the strong seasonality and stratification of pollen flow within the forest canopy and that individual taxa had variable sensitivity to seasonal and annual changes in environmental conditions, manifested as changes in pollen productivity. We conclude that modern pollen rain samples capture the reproductive response of moist tropical plants to short-term environmental change, but that consequently, pollen rain-based calibrations need to include longer sampling periods ($7 years) to reflect the full range of natural variability in the pollen output of a forest and simulate the time-averaging present in sediment samples. Our results also demonstrate that over the long-term, pollen traps placed in the forest understory are representative samples of the pollen output of both canopy and understory vegetation. Aerial pollen traps, therefore, also represent an underutilized means of monitoring the pollen productivity and reproductive behavior of moist tropical forests.

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Agua Salud: A long-term research initiative in Panama

Presenter: Jefferson HALL

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Long term research sites are critical to understanding global change as provide opportunities to interpret environmental changes in reference to historical baselines and capture the effects of severe weather events like floods and droughts, events most likely to affect ecosystem dynamics. Located in the Province of Colon, Panama, the Agua Salud Facility at STRI emerged from the Agua Saud Project. Agua Salud was set up to study the ecosystem services provided by tropical forests and how they change with land use and climate change. Here we describe long term research projects, monitoring networks and datasets of Agua Salud. The Hydrology monitoring network consists of 13 weirs on streams of different land uses where stream flow is measured every 5 minutes. The secondary forest network consists of plots in 54 sites across the landscape. Associated with this network are two additional networks: 1) a liana removal plot network (30 sites) and 2) a nutrient addition experimental network where nitrogen (N), phosphorus (P), and both N and P are added 4 times a year (60 plots in 12 sites). Agua Salud also maintains a native species plantation consisting of 20 unique tree species mixtures and tree species enrichment planting experiments in both teak plantations and naturally regenerating secondary forest. Networks leverage basic, use-inspired, applied research, and natural history observations to address broad research questions linked to global change effects on tropical forest ecosystems and services.

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Assessing growth, overyielding, and mortality rates in monocultures and mixtures of five native tree species in a long-term plantation experiment in Panama

Presenter: Dide M. HORMES

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Tropical reforestation can provide benefits by sequestering carbon and potentially restoring ecosystem services. The success of a reforestation project is largely dependent on planting the right tree species, but finding a productive tree species to grow on Panama's nutrient poor soils has been proven challenging. Native tree species could potentially be a solution to the problem, but there is a lack of knowledge on the performance of native species in plantations. Planting trees in mixtures could also help increase the productivity of a plantation through resource partitioning or facilitation.
A long-term plantation experiment was set up in 2008 with five native tree species (*Anacardium excelsium, Dalbergia retusa, Pachira quinata, Tabebuia rosea* and *Terminalia amazonia*), planted in 267 plots with 21 treatments comprising monocultures and mixtures. The basal diameter and diameter at breast height of 22,267 trees was measured every year until 2015, and then every other year until 2021. The above-ground biomass (AGB) was determined using species-specific and treatment-specific allometric biomass equations, which were developed locally in 2021. I am currently analyzing this dataset to determine which treatments produce the most AGB per hectare. Additionally, I will analyze the productivity of mixtures compared to monocultures, the mortality rate of species and treatments and the changes in growth rate over time. To evaluate the consistency in (AGB) across different species and treatments, the variation in AGB among trees will be compared. Hopefully, the insights from this long-term plantation experiment can help select the best tree species for reforestation efforts.

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The scale and patterns of heart rot in live trees in a tropical rain forest

Presenter: Gregory S. GILBERT

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The trunks of forest trees store massive amounts of carbon, but fungi actively and invisibly decay wood inside even seemingly healthy trees. Wood decay fungi are responsible for loss of stored carbon of living trees, and structurally weakened trunks and root systems make trees susceptible to snapping and up-rooting in storms. Because there are usually no external signs of internal decay, measuring how much of the standing wood of a forest is intact is challenging without invasive techniques. We used acoustic tomography to measure patterns of wood decay in 1744 live trees (> 20 cm diameter) of 172 species on the 50-ha Forest Dynamics Plot on Barro Colorado Island. Across all species, a median of < 2% of the cross-sectional basal area showed signs of decay, but 15% of trees had > 20% decay. Across all scanned trees combined, 20% of the cumulative basal area live trees showed decay. Larger trees were more likely to show internal decay, with about one quarter of trees showing significant decay by the time they reach canopy height. Decay is usually greatest near the base of the trees, and spreading upward. Species varied greatly in severity of decay; 23% of species showed less than 2% decay while 9% of species averaged over 50% decay of basal area. Abundant species tended to show less wood decay than did locally rare species.

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Fitness consequences of traits associated with domestication in a tropical fruit tree, *Chrysophyllum cainito*

Presenter: Ingrid M. PARKER

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A central tenet of the evolutionary ecology of domestication is that anthropogenic selection for domestication traits leads to reduced fitness in the wild. Plants in the early stages of domestication allow us to study the interplay of human and natural selection in the ecological context of their wild habitat. *Chrysophyllum cainito* (Sapotaceae), or caimito, shows a strong domestication signature for fruit and seed traits. Its putative center of origin is the Panamanian isthmus. We studied the consequences of domestication on early life history traits in caimito, comparing wild and cultivated genotypes. In addition to laboratory and greenhouse experiments with seeds, we tracked survival and growth over 15 years in experimental plantings in the ancestral understory habitat. We established plots of randomized wild and cultivated provenances in the forest understory in two regions of central Panama with contrasting intensity of dry-season drought, Pipeline Road and Parque Natural Metropolitano. We tested for tradeoffs in performance in wild vs. semi-cultivated environments by comparing the results from these experiments to performance of trees from the same maternal families over 15 years in two semi-natural plantations at the Ciudad Del Arbol forest restoration site.

Seeds from cultivated genotypes were less resistant to desiccation than those from wild type trees, and the cultivated seeds germinated faster in both the greenhouse and the field. As expected, in the wild environment wild-type seeds and fruits had greater germination and establishment success, although only in one year. Patterns of survival, growth, and susceptibility to pathogens and herbivores showed few differences between wild and cultivated genotypes. Surprisingly, we found no evidence for a tradeoff between seedling survival in the deep shade of the understory and sapling growth rates in our plantations, where some trees have reached >20cm diameter.

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Long-term dynamics of vascular epiphytes in a tropical lowland forest in Panama

Presenter: Lars Erik JANNER

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Understanding the mechanisms that form local community structures is one of the central topics of community ecology. In tropical rainforests, however, almost all knowledge derives from trees, leaving dynamics of communities in the canopy almost neglected. This study tries to fill that gap by focusing on the structure and long-term community dynamics of vascular epiphytes in a Panamanian lowland forest. As negative biotic interactions are thought to be negligible in vascular epiphytes, they represent an ideal model organism to investigate biodiversity changes and species stratification. Epiphyte community data have been gathered in the San Lorenzo National Park, the world-wide only long-term plot dedicated to epiphyte research, using a canopy crane and tree climbing techniques. Currently, the third census of vascular epiphytes is now carried out, allowing the analysis of unique community data of vascular epiphytes over the last 25 years. Data from an area of 0,36 ha have been used to provide first insights into stochastic and deterministic processes influencing epiphytic assemblages.

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Fleshy fungi of Barro Colorado Island

Presenter: Clark L. OVREBO

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Clark L. OVREBO

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Tropical areas support a rich diversity of fleshy fungi of the class Agaricomycetes, the class that includes mushrooms, bracket fungi, puffballs, earthstars, jelly fungi and stinkhorns. These fungal groups are well-represented on Barro Colorado Island (BCI) and belong to about 70 genera. Fleshy Ascomycota can also be common. The focus of this research concerns mainly the gilled mushrooms. Their trophic statuses include both saprotrophic and ectomycorrhizal fungi with saprotrophic fungi being the most common. Saprotrophic substrata include leaves, twigs, logs and soil. *Marasmius, Gymnopus, Lepiota s.l., Agaricus, Gerronema, Hydropus s.l.,* and *Pluteus* are among the most common saprotrophic genera. For saprotrophs, three new species of *Marasmius,* one species each of *Hygrocybe, Camarophyllus, Volvolepiota, Rhodocybe, Lepistella,* and *Alboleptonia* were described as new from BCI. Ectotroph genera are not uncommon on BCI. These genera include *Amanita, Russula, Lactarius* and *Boletus* with *Russula panamae* described as new. More work needs to been done to determine the ectotroph tree partners of these genera. The work on identifying the collections continues and molecular approach is helping to establish generic limits which cannot be done with morphology alone, as is the case with *Hydropus s.l.*

P18

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Following Alice down the tapir hollow: Pursuing life histories for two tapir skeletons in the STRI Archaeology Labs' Vertebrate Osteology Reference Collection

Presenter: Nicole E. SMITH-GUZMÁN

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Zooarchaeology, the study of faunal remains from archaeological sites, often requires the use of modern faunal reference skeletons for the identification of archaeological specimens. For over five decades, Richard Cooke built a large skeletal reference collection in the STRI Archaeology labs, including > 2,000 extant vertebrate species from Panama. Two tapir skeletons were incorporated into this collection in the 1980s; however, both lacked provenance records. In 2023, we began tracing oral and written histories of tapirs on BCI in an effort to verify whether the reference collection tapirs might correspond to any of the named BCI tapirs documented in books, papers, newsletter articles, and photographs throughout the 1970s and 1980s. In particular, a notorious BCI tapir named "Alice" died on September 12, 1988—the same month and year that the most complete of the reference collection tapirs arrived at the STRI archaeology lab. By comparing osseous features present on the tapir skeletons with oral and written histories of the BCI tapirs, we were able to confirm that neither of the reference collection tapir skeletons likely belong to "Alice." However, a partial skeleton incorporated into the collection prior to 1988 may indeed belong to "Louie"—a male tapir frequently observed on BCI who died in 1980. Based on observed perimortem gunshot trauma to the cranium and pertinent oral history from a senior archaeology lab member, the second, more complete tapir skeleton likely pertains to an animal recovered from poachers by the Instituto Nacional de Recursos Naturales Renovables (INRENARE) in 1988 that was donated to STRI. Through this project, we collated curious and delightful details for the tapir population on BCI, including their re-introduction to the island in 1964, often human-supplemented diet, and behavioral antics recorded by STRI biologists. This compilation has been transformed into a short documentary for archival, conservation, and educational purposes.

BARRO COLORADO ISLAND 100 YEARS

Smithsonian
Tropical Research Institute

June | Junio 19

Abstracts
Resúmenes

June 19 • 8:30 • Gamboa Grand Ballroom

Who is your neighbor? Eavesdropping enemies and nearby signalers in mixed species assemblages

Presenter: Alex TRILLO

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Alex TRILLO[1,6], Ximena BERNAL[2,6], Michael CALDWELL[1,6], Richard HALL[3], Hannah TER HOFSTEDE[4], Ciara KERNAN[5], and Rachel PAGE[6]

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Males of species with similar breeding requirements often display from mixed-species assemblages. While many studies explore how signaling conspecific neighbors mediate eavesdropping enemy attraction and risks suffered by a focal individual, less is known about how heterospecific neighbors shape these risks. Our research shows that interactions between heterospecific neighbors at frog choruses can influence eavesdropper attraction and alter selective pressures on signalers. We discuss models that illustrate how the relative attractiveness of neighbors can alter eavesdropper risks faced by signalers, and how this change in eavesdropper risk, especially when eavesdroppers are disease vectors, can influence disease transmission dynamics. Eavesdropper risks mediated by heterospecific neighbors may also alter frog signaling behavior. We discuss the use of an acoustic camera at natural frog choruses paired with mesocosm trials to investigate whether frogs alter their signaling behavior in response to eavesdropper risks associated with heterospecific signalers. This work illustrates how inter-trophic interactions are mediated by the spatial and temporal distribution of signalers within mixed-species mating assemblages.

June 19 • 8:40 • Gamboa Grand Ballroom

Eavesdropping micropredators and their unforeseen effects on communication systems

Presenter: Ximena E. BERNAL

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Animal signals are susceptible to being intercepted by eavesdropping enemies. These non-target receivers exploit the communication system of their prey using their signal to detect and localize their victim. While ‘true’ predators impose clear, direct costs, micropredators are expected to have more subtle effects as they generate intensity-dependent effects. Using frog-biting midges as a case study, I provide a synthesis of research and discovery revealing unique aspects of eavesdropping micropredators and their effects on frog communication systems. From natural history to previously unforeseen effects of frog-biting midges on the communication system of their victim, work from our research team investigating this system in Gamboa and its surrounding areas has laid the foundation for broadening our understanding of the complex nature of communication networks.

June 19 • 8:50 • Gamboa Grand Ballroom

The role of heterospecifics and habitat on signal design

Presenter: Katherine GONZALEZ

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Identifying and understanding the factors associated with signal design is critical in the study of animal communication. Among those factors, the signaling environment can affect signal structure by imposing challenges to communication. For example, social environments increase masking interference, shaping acoustic signals toward differentiation. An additional challenge that signalers face is reaching their target receiver. Structural characteristics of the acoustic environment, such as signaling height in the forest, may influence the transmission of acoustic signals. The Acoustic Adaptation Hypothesis proposes that the environment favors acoustic signals that experience less power loss and maintain their integrity across distances to increase detection by target receivers. With differences in transmission properties such as amplitude and fidelity, signalers across the vertical strata of the forest may differentially attract target and non-target receivers. We examined how signal environments influence the structure of acoustic signals using two approaches. To address the role of communicating among heterospecific signalers, we systematically review studies that investigate the Acoustic Space Partitioning Hypothesis, which examines how signalers communicate in mixed-species aggregations. While over half of the studies support this hypothesis, methodological and conceptual inconsistencies are widespread. We discuss the evidence for signal differentiation and the resulting patterns, including an often neglected component, the receiver. To examine the role of the microhabitat, we experimentally study the influence of forest height on signal transmission efficiency in a Panamanian anuran community. We report evidence that frog calls of different species vary in the degree of attenuation experienced at the canopy and understory, with few species following the predictions from the Acoustic Adaptation Hypothesis. Finally, we discuss ongoing work examining how non-target receivers, such as bats and midges, respond to frog calls across the forest's vertical strata.

June 19 • 9:00 • Gamboa Grand Ballroom

Call-timing responses to frequency- and amplitude-modulated stimuli depend on immediate acoustic context in a frog with similarly modulated calls

Presenter: Luke C LARTER

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Male frogs court females from within dense, noisy, choruses. The way female sensory systems parse multiple calls encountered closely in time generates preferences for calls at certain temporal positions, selecting for mechanisms allowing males to call at preferred times relative to rivals. These resulting call-timing responses are accomplished proximately by male sensory systems, as they continuously evaluate the fluctuating acoustic scene generated by their competitors for opportune times to call. Túngara frogs form dense choruses and produce highly amplitude- and frequency-modulated calls. We investigated how similarly amplitude- and frequency- modulated playback stimuli influenced male call-timing responses. Results revealed that different frequencies present throughout this species' call differed strongly in their degree of call inhibition. Additionally, lower amplitudes were less inhibitory at most frequencies. However, how inhibitory a given frequency/amplitude combination was varied strikingly depending upon which frequency directly preceded it. Thus, how inhibitory an acoustic moment was perceived to be was contingent upon its immediate acoustic context. These results elucidate unexpected findings from previous túngara frog chorusing studies, demonstrating the utility of detailed explorations of the perceptual drivers of call-timing responses. Furthermore, the revealed moment-to-moment context-dependence of perception highlights the complexities intrinsic to sensory-driven sexual selection occurring within cacophonous choruses.

June 19 • 9:10 • Gamboa Grand Ballroom

Humans and animals share acoustic preferences

Presenter: Logan S. JAMES

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Logan S. JAMES[1,2,3,4], Sarah C. WOOLLEY[1], Jon T. SAKATA[1], Courtney B. HILTON[4,5], Samuel A. MEHR[4,5], and Michael J. RYAN[2,3]

1. McGill University. 2. University of Texas at Austin. 3. Smithsonian Tropical Research Institute. 4. Yale University. 5. University of Auckland

Many animals use acoustic signals to attract others. Biases in signal perception, processing, and preferences impact responses of receivers, and these biases need not have coevolved with the signals themselves. Indeed, Darwin noted that some animals “have nearly the same taste for the beautiful as we have,” suggesting that fundamental perceptual biases may produce common aesthetic judgements across species. However, few studies have directly asked whether animals share acoustic preferences. Here, we collected preference data from one animal (humans; n > 4,000) for acoustic signals with known conspecific preferences (n = 20, covering frogs, mammals, birds, and insects). We find that, broadly, humans agree with the acoustic preferences of other species. We also find intriguing variation; e.g., human preferences are not concordant with animals when the stimuli differ in the developmental experiences of the signaler, but humans do agree with animals when the stimuli differ in measures of complexity or social context. Overall, these results are consistent with the theory that preferences for signals can evolve separately from the signals themselves, and confirm a century-old hunch about beauty in nature.

June 19 • 9:20 • Gamboa Grand Ballroom

Relationship formation in vampire bats without forced proximity

Presenter: M. May DIXON

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M. May DIXON[1,2], Guadalupe A. GARCIA[1], Jorge G. LOPEZ[1], Rachel A. PAGE[1], and Gerald G. CARTER[1,2]

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Vampire bats (*Desmodus rotundus*) form individualized cooperative relationships through escalations of clustering, allogrooming, and food sharing. Previous experiments on social bonding in vampire bats have jumpstarted new relationships by housing unfamiliar bats together in the same cage. Although this 'forced proximity' condition encourages social bonding, it also reduces the subjects' ability to avoid strangers, and largely removes the effect of individual movements on social integration. In this study, we house three social groups in separate flight cages for two years, document their allogrooming networks, then open portals between the three cages to allow individuals to visit new spaces and meet outgroup bats. Using multiple biologging methods, we track their grooming and association rates before, during, and after this social merging of groups. By allowing spatial and social exploration during relationship formation, we hope to create a more ecologically realistic model of social bonding dynamics.

June 19 • 9:30 • Gamboa Grand Ballroom

The impacts of light on frugivorous bat foraging behavior

Presenter: Lauren A. NORWOOD

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Lauren A. NORWOOD[1], Mary Heather B. JINGCO[1], Luisa F. GÓMEZ-FEUILLET[1], M. May DIXON[1,2], Jay J. FALK[1,3], Logan S. JAMES[1,4], and Rachel A. PAGE[1]

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Light patterns have shaped the evolution of animal behavior for billions of years, but these patterns are becoming increasingly disrupted by anthropogenic light, which is rapidly spreading into more remote spaces. Researchers have begun investigating the influence a brighter world may have on wildlife populations, especially for nocturnal species. For example, the behavior of many bat species has been shown to be strongly influenced by light levels, both natural (e.g., moon cycles) and anthropogenic. In this experiment, we sought to understand whether Neotropical frugivorous bats display behavioral plasticity for foraging in brighter environments based on their previous experience with natural and anthropogenic light. We captured individuals from bat populations whose roosts differed in brightness, and presented them with a food retrieval task in an artificially lit space and in an unlit space. Using a comparative approach, we discuss our results in the context of species' roosting behavior and emergence time, both of which may impact conservation in these and other nocturnal species.

June 19 • 9:35 • Gamboa Grand Ballroom

Bat predation on sleeping birds: a novel foraging strategy for an eavesdropping specialist?

Presenter: Mary Heather B. JINGCO

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Neotropical leaf-nosed bats from the family Phyllostomidae display a spectacularly broad diversity of diets. Among animal-eating phyllostomids, the fringe-lipped bat (*Trachops cirrhosus*) is a passive gleaner that relies primarily on prey-emitted sounds to locate prey. It hunts frogs by eavesdropping on mating calls, but also feeds on arthropods, reptiles, and other bat species. Observations of culled remains below roosts and fecal metabarcoding analyses revealed that these bats also consume diurnally active prey, including manakins and hummingbirds. We investigated the ability of *T. cirrhosus* to localize silent, motionless prey – sleeping birds – and assessed its efficacy as a bird and nest predator in artificial and natural settings. We investigated these questions in captive experiments by quantifying the behavioral responses of *T. cirrhosus* to mounts of bird species of varying size and to nests with eggs, and by installing trail cameras in known foraging areas provisioned with these same items in the wild. Our results not only provide context regarding bat foraging abilities, but also shed light on a relatively unexplored source of predation of small Neotropical birds.

June 19 • 9:40 • Gamboa Grand Ballroom

Unraveling the sexual phenotype of a tropical hummingbird

Presenter: Jay Jinsing FALK

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Sexual phenotypes are one of the main forms of organismal diversity, and research at the Smithsonian Tropical Research Institute has been profoundly impactful in answering how and why the sexes evolve. Recent attention on sex-specific polymorphisms has offered a powerfully integrative approach to understanding both the adaptive maintenance of diversity and the genetic basis of sexual phenotypes. I will review previous and ongoing research at STRI on one such polymorphism in a widespread Neotropical hummingbird, the white-necked jacobin (*Florisuga mellivora*). In this species, males and females appear to be sexually dimorphic in plumage color, yet close inspection reveals that some females (~20%) are nearly indistinguishable from males. Through long-term population monitoring and behavioral experiments, we found that this female-specific polymorphism is likely maintained because females mimic more aggressive males in order to gain access to precious food resources. Furthermore, current research into the genetic basis of this polymorphism shows that a very small region on a single gene likely controls the suite of color differences in the two female morphs of this species. I discuss how social selection and cross-sexual transfer, two concepts developed at STRI, are critical for understanding the evolution of sexual phenotypes in hummingbirds and beyond.

June 19 • 9:50 • Gamboa Grand Ballroom

The evolution of nocturnal behavior in bees

Presenter: William T. WCISLO

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As a result of studies of natural history of *Megalopta* bees, these nocturnal bees have become the non-traditional model organism to study i) the evolutionary transitions between solitary and social behavior–one of the major transitions in evolution; and ii) the evolution of dim-light foraging in bees, documenting the physiological and neurobiological changes that enable vision in extreme dim-light conditions. Together, these studies demonstrate the critical importance of behavior as a pacemaker of evolutionary change.

June 19 • 8:30 • Las Jacarandas

The seeds of coexistence: Seed chemistry explains co-occurrence of *Psychotria* species along a moisture gradient

Presenter: Gerald F. SCHNEIDER

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The phenomenon of “species swarms”, or genera with a high degree of sympatry among their species, has long been of interest as a potential gateway to understanding mechanisms of diversification and coexistence in tropical plant communities. The closely allied genera *Psychotria* and *Palicourea* represent one such swarm, with over 2,000 total species and 20 species on the 1,560 ha island of Barro Colorado, Panama. Among the Psychotria-Palicourea of Barro Colorado Island (BCI), previous research has explored potential niche differentiation across axes of physiological traits shaped by abiotic habitat and defensive traits shaped by biotic interactions. The coexistence of *Psychotria-Palicourea* species has not yet been fully explained along these axes. However, a potentially explanatory set of interactions had yet to be considered, namely those centered on fruit and seeds. Neotropical *Psychotria* and *Palicourea* seeds are both dispersed exclusively by birds, and this avian specialization may be linked to fruit secondary metabolites, as has been documented for the genus *Capsicum* and its capsaicinoids. Further, a growing body of research has indicated that seed secondary metabolites and their role in mediating seed-microbial interactions may be a key factor in determining the spatiotemporal distribution of survival to the seedling stage.

Focusing on the fruit and seed secondary metabolite traits of the 20 *Psychotria-Palicourea* species of BCI, we investigated whether these groups of secondary metabolites could help explain species co-occurrence along abiotic habitat gradients. Utilizing existing data on the co-occurrence of these species along gradients of light availability and soil moisture, we collected ripe fruit with mature seeds for untargeted metabolomic analysis. We also collected leaves to pinpoint fruit-specific metabolites by contrast. Untargeted metabolomics were conducted using UPLC-MS/MS with a workflow consisting of MZmine3 peak processing, GNPS molecular networking, and SIRIUS annotation. While controlling for phylogeny in partial Mantel tests, we then compared species-pairwise distance matrices of chemical structural composition and habitat centroids, both for the full secondary metabolome and for metabolic pathway classes, e.g. terpenoids. Seed chemical similarity was negatively correlated with soil moisture habitat affinity, both for the full seed metabolome (Mantel $r = -0.15$, $p = 0.05$) and for alkaloids ($r = -0.16$, $p = 0.05$) and terpenoids ($r = -0.24$, $p = 0.02$). Further, no aspects of the leaf metabolome were significantly correlated with habitat affinity. Our results suggest that moisture-associated seed antagonists and/or mutualists are key to determining which species of the *Psychotria-Palicourea* swarm can co-occur.

June 19 • 8:40 • Las Jacarandas

Resistance gene diversity and the eco-evolutionary dynamics of tropical tree seedlings

Presenter: James H. MARDEN

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Genetic determinants of pathogen resistance are well known in crops but have been examined minimally in natural communities. We merged the Janzen-Connell hypothesis, about seed dispersal providing escape from parent-associated pathogens and pests, with the genetics of plant immunity, by testing the hypothesis that tropical tree seedlings sharing resistance (R) alleles with conspecific neighbors have increased co-susceptibility and reduced fitness. In naturally occurring seedlings of thirteen taxonomically diverse tree species in a tropical forest, conspecific negative density-dependent mortality (CNDD) was explained by two independent factors: non-neutral R gene protein coding diversity in the local population, and spatial variation of heritable defense-related gene expression, indicating that more diverse and better-mixed pathogen resistance traits reduce CNDD. In an experimental test, seedlings carrying a dominant resistance allele (R+) had 18% more growth, but only when exposed to soil from conspecific trees carrying only susceptible (R-) alleles. The allele-sharing context was also associated with differences in defense gene expression, abundance and strain identity of particular root-associated bacteria putatively competing for soil nitrogen, and seedling nitrogen-related gene expression. Simulation showed that a small cost of resistance could maintain genetic polymorphism with the observed frequencies of resistant and susceptible alleles. Ultimately, these results show strong relationships between R gene allelic diversity and the microbe-mediated growth and survival of seedlings, creating balancing selection maintaining alleles affecting eco-evolutionary dynamics.

June 19 • 8:50 • Las Jacarandas

Eight new species of fungi in the genus *Calonectria* and their role as regulators of plant diversity on BCI

Presenter: Hernán D. CAPADOR-BARRETO

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Hernán D. CAPADOR-BARRETO[1], Omayra MELENDEZ[1], Mateo VAUCOULEUR[1], Erin R. SPEAR[1], and Kirk BRODERS[1,2]

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Soilborne fungi are deemed as important players in the maintenance of the exuberant plant diversity in tropical forests. According to the Janzen-Connell hypothesis (JCH), host plants at high densities and close to adults of the same species will suffer from higher mortality due to specialized pathogens, thereby preventing dominance of common species and contributing to plant coexistence. However, the identity of the fungi involved in this process is rarely determined. In this study, we aimed to characterize the diversity, pathogenicity, and distribution of soilborne fungal pathogens responsible for Janzen and Connel effects in a lowland tropical forest in the Republic of Panamá. From a collection of 29 isolates infecting seedlings of tropical tree species from central Panama, we identified and propose 8 new species of Calonectria based six molecular barcodes (βtub, cmdA, his3, rpb2, tef1, ITS) and morphological characters. Furthermore, we assessed pathogenicity of these isolates and found that they are lethal to early germinating seedlings and capable to infect stems and leaves of older seedlings of *Virola nobilis* (MYRISTICACEAE). Furthermore, we have evidence that even though *Calonectria* are thought of as generalist pathogens, they display effective specialization, with larger growth in their original host (local) than in nonlocal hosts. Finally, based on our results and traits reported in the literature for this genus, we propose mechanisms by which these pathogens are playing an important role regulating tropical plant diversity.

June 19 • 9:00 • Las Jacarandas

Understanding disease-driven density dependence and coexistence

Presenter: Marco VISSER

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Marco VISSER and Matteo DETTO

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In the 1970s, Janzen and Connell proposed that tree species (hosts) coexist due to the stabilizing actions of specialized enemies. Today, a growing body of empirical research indicates that pathogens are influential in tropical forests, potentially explaining species coexistence and the observed variation in species abundances by being the primary force behind conspecific negative density dependence (CNDD). However, accurately quantifying CNDD has proven challenging, leading to varied and difficult-to-interpret macroecological patterns that even suggest destabilized communities. In this talk, I take a step back to delve into the fundamental mechanisms through which pathogens as disease-causing agents influence plant demographic rates such as survival. By employing analytically trackable epidemic models built on first principles, we offer a more mechanistic lens on how pathogen dynamics can drive empirical patterns of conspecific density-depenence in natural ecosystems. Our models explicitly incorporate host and pathogen traits, such as transmission allocation and recovery patterns. Our models provide a reconciling framework for seemingly contrasting observations in the field, as illustrated by two key results. First, our findings reveal that a higher magnitude of CNDD for rare species might serve as a distinctive hallmark of disease-induced density dependence that emerge from Janzen-Connell type-interactions. Second, our results also contextualize the empirical trends where rare species appear to suffer more from CNDD and offer alternative interpretations. Our findings propose that the heightened CNDD observed in rare species may not signal vulnerability to pathogens but rather a lack of exposure to the epidemic's peak effects. We hypothesize that stronger CNDD in rare species paradoxically fully aligns with the Janzen-Connell hypothesis, and indicates that rarity may protect against the full impact of diseases. This work therefore reconciles empirical trends with core ecological theory, suggesting that stronger CNDD in rare species may be a macroecological signal of their relative resilience and stability, due to inherent fundamental properties of disease dynamics. We conclude by proposing novel approaches, that connect theoretical forecasts with empirical data, for evaluating disease-driven density-dependence, coexistence and evolution of host-diversity. Our models provide both a stronger basis for Janzen–Connell, delivering a wider lens that can yield important insights into the maintenance of diversity in these increasingly threatened systems.

June 19 • 9:10 • Las Jacarandas

Janzen-Connell effects and habitat-induced aggregation synergistically promote species coexistence

Presenter: Daniel J. B. SMITH

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Daniel J. B. SMITH

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Both Janzen-Connell (JC) effects and habitat partitioning are coexistence mechanisms that have received empirical support in species-rich tree communities. Despite substantial evidence of their simultaneous operation, the theoretical implications of how their interactions shape species richness remain underdeveloped. Here, I analyze a spatially explicit model that incorporates both processes. While neither JC-effects nor habitat partitioning in isolation are likely to maintain high species richness when parameterized with realistic values, I find that the interaction of the mechanisms can do so if habitat specialization causes species to aggregate in locations where they have high fitness. The stabilizing effect of JC-effect – habitat partitioning interactions is readily quantified by the spatial covariance of their strengths, an empirically measurable quantity. In contrast, species aggregation associated with dispersal limitation decreases the ability for JC-effects to maintain coexistence. JC-effect – habitat partitioning interactions and JC-effect – dispersal limitation interactions therefore generate opposite relationships between intra-specific aggregation and species richness (positive and negative, respectively). The results of this study provide a framework to quantify how the interactions between JC-effects, habitat partitioning, and dispersal limitation and their downstream effects on species' spatial distributions affect coexistence.

June 19 • 9:20 • Las Jacarandas

Spatial repulsion among conspecific adult trees on BCI

Presenter: Michael KALYUZHNY

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For multiple species to coexist, it is necessary that as species increase in abundance, they suffer from Conspecific Negative Density Dependence (CNDD). For trees, there is ample evidence for such negative effects of abundance on the survival and frequency of juveniles, typically on short spatial scales. Despite this short distance “repulsion” of juveniles, adult trees are generally spatially clumped, and there is little evidence that CNDD acting on juveniles propagates to the adult stage, casting doubt on its importance for coexistence.

However, evidence on aggregation were previously obtained by comparing the spatial distribution of adults to a random placement across the landscape. We re-examine the spatial distributions of adult trees on BCI, comparing them to a calibrated neutral model of stochastic birth-death and limited dispersal, using estimated dispersal kernels.

When compared to a model of limited dispersal, the adults of almost all tree species are strongly and significantly overdispersed on scales of at least 100 meters, while several habitat and gap specialists are more aggregated. We further demonstrate using simulations that such strong repulsion can only be the result of CNDD being substantially stronger than Heterospecific Negative Density Dependence (HNDD).

These results suggest that the CNDD commonly found in juveniles propagates to adults, strongly influencing their spatial distribution. Furthermore, the result of CNDD >> HNDD implies large niche differences between species, with the potential to stabilize coexistence. Our results demonstrate the power of using the limited dispersal null to detect biotic interactions and habitat associations.

June 19 • 9:30 • Las Jacarandas

A spatial signal of niche differentiation among woody plants in tropical forests

Presenter: Rafael D'ANDREA

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Explaining diversity in tropical forests remains a challenge in community ecology. Theory suggests that species differences may stabilize communities by mitigating competition, whereas species similarities might foster diversity by equalizing fitness levels, thereby delaying competitive exclusion. This dynamic may result in species clustering, where distinct clusters exhibit niche differentiation while member species within a cluster share similar niche strategies. Our study investigates this phenomenon of partial niche differentiation in Barro Colorado Island, Panama, and La Planada, Colombia, focusing on the spatial clustering of woody plant species and their association with local soil nutrient variations. Our analysis reveals that species within both forests exhibited significant spatial clustering. Those clusters were spatially linked to distinct local soil nutrient concentrations, suggesting the existence of niches characterized by specific nutrient profiles. New recruits were nearly twice as likely to recruit within their nutrient niche than in other clusters' nutrient niches. A decision tree algorithm showed that local soil conditions correctly predicted cluster membership with up to 85% accuracy. Iron, zinc, phosphorus, manganese, and soil pH were among the best predictors of species clusters. Our findings corroborate theoretical predictions of partial niche differentiation in highly diverse communities and elucidate the relationship between soil nutrients and woody plant distribution in two tropical forests with distinct soil types and diversity levels, offering new insights into the drivers of diversity in tropical forests.

June 19 • 9:40 • Las Jacarandas

Non-neutral forest gap dynamics promote tree species and functional diversity in BCI

Presenter: Annette OSTLING

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Dylan DEBAUN[1,4], Michael KALYUZHNY[2,4], and Annette OSTLING[3,4]

1. American Museum of Natural History. 2. The Hebrew University of Jersulem. 3. Integrative Biology, University of Texas at Austin. 4. University of Michigan, Ann Arbor

Gap dynamics, succession following the opening of small forest canopy gaps, have been hypothesized to be driven by successional niches promoting diversity. This view has been challenged by suggestions that gap dynamics are largely stochastic and driven by dispersal limitation. However, the relative abundance of species in gaps has yet to be explicitly compared with simulations of what is expected under dispersal limitation and stochasticity. Previous works have instead compared gaps to non-gaps or gaps of different ages or sizes, but this does not control for differences in initial composition or in the nearby community providing recruits, and thus cannot pinpoint in which communities (gaps vs. non-gaps) or at what time scales the dynamics are shaped by deterministic niche forces. This requires comparison of both gaps and non-gaps with a neutral model. Using such a model also allows, for the first time to our knowledge, quantitatively studying diversity and composition at the level of the entire set of gaps in a forest (gap metacommunity), which requires comparison with an external reference (another forest or a model. Here we carry out such an explicit test by comparing the observed dynamics of adult trees in the gaps of BCI to a neutral model initialized by the first BCI census. We find that gaps deviate strongly from neutral-predicted dynamics towards pioneer traits and demography, while non-gaps deviate in the opposite direction, with elevated functional diversity in both. Gaps show larger species diversity than neutral expectations, due to the decline of regionally common shade-tolerant species and increase in rarer pioneers. These departures of gaps from neutral expectations can be seen out to decades after the sites included in our gap metacommunity were first known to be gaps. Along with elevated spatial compositional turnover between gaps and non-gaps, these results confirm a substantial role of successional niches in gap dynamics, propagating to the adult stage and enhancing functional diversity and alpha and beta species diversity.

June 19 • 9:50 • Las Jacarandas

Symmetric intransitive loop competition can lead to stable coexistence for odd but not even numbers of species

Presenter: Daniel P. MAES

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Intransitive loops of competition are akin to a game of Rock-Paper-Scissors (RPS) where there is not one dominant competitor (e.g. no dominant winning strategy in RPS). These interactions have been observed among a variety of organisms–including plankton, lizards, and vascular plants–and provide a potential means of competitive coexistence fundamentally different than classically studied niche differences, in which all species impact themselves more than other species. A prevalent hypothesis about intransitive loop interactions is that loops including an even number of species are unstable whereas ones of odd length are stable. Using a Lotka-Volterra competition model, we study the outcomes of such intransitive loop dynamics. We employ an analytical approach to communities with an arbitrary number of species interacting through a single intransitive loop that is “symmetric”, meaning that interaction strengths between pairs of interacting species in the loop are constant across interaction pairs. We show that for such symmetric loops, the coexistence equilibrium point of the Lotka-Volterra competition model with even-length loops is indeed always locally unstable, while for odd-length loops local stability is possible. We also use numerical analyses to show that these results are robust to small variations in competition strengths across species pairs. These results solidify a long-standing but unproved assertion that odd-length intransitive loops can lead to stable coexistence. However, we also find that the range of competition strengths allowing for this stable coexistence shrinks as the number of species increases. This points to the importance of further study of more complex interaction structures involving intransitive loops, to better understand them as a potential means by which competing species coexist in nature.

June 19 • 8:30 • Camino de Cruces

The effects of seasonality on the expression and evolution of antimicrobial peptides in the Slender Anole (*Anolis apletophallus*)

Presenter: Yanileth F. LOPEZ-TACOAMAN

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Understanding the impact of seasonality on the expression of antimicrobial peptides (AMPs) is key to understanding the evolutionary dynamics and immunology of many vertebrates. I leveraged the recently published genome of the slender anole and other closely related lizard species to explore the evolutionary history and dynamics of AMPs, and to assess their expression across different tissues under varying environmental conditions. I used a combination of morphological, physiological, and molecular data to answer two primary research questions: 1) What are the evolutionary dynamics of antimicrobial peptides in the slender anole? 2) What are the expression patterns of key antimicrobial genes across different tissues and environmental conditions? To do this, I collected 120 adult lizards during wet and dry seasons at a lowland tropical forest site in central Panama. Each individual was cataloged, measured for morphological and physiological traits, and gene expression was quantified for known AMP genes using quantitative PCR. This study sheds light on the adaptability of the slender anole's immune system to dynamic tropical environments and potential correlations between AMP-related gene expression and seasonality. My research contributes to understanding of host-pathogen interactions in tropical ecosystems, with implications for biodiversity conservation under climate change. Finally, my findings lay the foundation for broader investigations into AMPs across diverse reptile species to gain insight into evolutionary dynamics and conservation.

June 19 • 8:35 • Camino de Cruces

A thermoconforming forest lizard alters heat-shock protein network expression in response to acute thermal stress

Presenter: Kelly Lin WUTHRICH

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Increasing temperatures caused by climate change are predicted to be particularly harmful for tropical thermoconforming ectotherms, which have evolved in a historically constant climate and do not use behavior to regulate body temperature. These organisms can initiate cellular- protective mechanisms by upregulating expression of genes such as those in heat-shock protein networks to cope with increasing temperature. However, whether expression of heat-shock protein networks can be altered in response to acute thermal stress has not been documented in most organisms. We studied how genes across heat-shock protein networks were differentially expressed in response to increasing temperature in the slender anole (*Anolis apletophallus*). Specifically, we tested how genes associated with the hsp40, hsp70, hsp90, and hsp110 networks changed in expression in brain, muscle, and liver tissues in response to both a mild (32C) and more extreme (35C) heat shock that persisted for 3 h. We found that both treatments caused upregulation of some but not all genes in each network, and that there was substantial overlap in the genes that were upregulated among tissues and between treatments. Our results highlight the importance of heat-shock protein network expression in the response of tropical, thermoconforming ectotherms to increasing temperature, and have implications for understanding how these species might persist in a rapidly changing environment.

June 19 • 8:40 • Camino de Cruces

Lizard gut microbiomes mediate host survival during environmental change

Presenter: Claire E. WILLIAMS

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As rising temperatures threaten biodiversity worldwide, tropical ectotherms are particularly vulnerable due to their narrow thermal tolerance ranges. Most studies of ectotherm responses to rapid environmental change focus on tolerance traits of the host. Our work examines the entire holobiont, including gut microbes that may affect thermal physiology as they can change rapidly in response to environmental conditions. While most studies examining climate change at the host-microbiome interface happen in laboratory settings, we examined this in situ, by transplanting slender anoles (Anolis apletophallus) from a mainland population to ten islands in the Panama Canal—all warmer than the source environment. We collected fecal samples from all individuals (N = 80 per island) prior to transplantation, and repeatedly in the weeks afterwards to observe how shifts in gut microbiomes (via 16S rRNA sequencing) may relate to changing host thermal tolerance as they acclimated to warmer island environments. We found that gut microbiomes on newly transplanted islands changed rapidly after transplantation and converge toward that of individuals on islands which had been transplanted in previous years. We also found that selection on gut microbiome composition played a role in this shift, as lizards with certain gut microbiota compositions were more likely to survive. Further work testing microbial contributions to thermal tolerance using fecal transplants is currently underway. Our discoveries will provide new insight into how shifts in microbiomes may mitigate or exacerbate climate change impacts on host fitness on our rapidly changing planet.

June 19 • 8:50 • Camino de Cruces

Parasite removal alters thermal tolerance in a tropical lizard

Presenter: Leah BAKEWELL

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Climate change can influence host-parasite dynamics by altering the abundance and distribution of parasites. These changes can lead to increased parasite loads or exposure to novel parasites, both of which can impact host performance and fitness. In particular, parasites can impact both the immune system and the response to thermal stress, and the impact of shifting climates and parasites are likely to be most extreme in thermoconforming tropical forest lizards. We used antiparasitic drugs (Ivermectin and Praziquantel) targeting either roundworms or flatworms to test how removal of different types of parasites would impact immune performance and thermal tolerance in the Panamanian slender anole (*Anolis apletophallus*). Treatment with Ivermectin reduced nematode infection and praziquantel decreased the intensity of cestodes. Immune function was not affected by antiparasitic treatment. Finally, antiparasitic treatment increased voluntary thermal maximum, a measure of upper thermal tolerance. Our results highlight that climate-altered parasitism might reduce the ability of thermoconforming lizards to tolerate increasing temperatures during rapid environmental shifts.

June 19 • 9:00 • Camino de Cruces

Understanding the interplaybetween temperature and inheritance shaping iridescence in the Neotropical butterfly *Parides sesostris*

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Leo Tomás CAMINO, Juliette RUBIN, and Owen McMILLAN

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Coloration in nature is one of the essential and most diverse signals in the animal world. Iridescence, a rare type of coloration displayed by many butterflies, is created by specific nano-structures. The Parides genus, endemic to the Neotropics, presents two game-changing properties for studying the ecological and genetic implications of structural coloration: male-specific iridescence and sexually-specific mimicry. Although these butterflies possess great potential to become a modern experimental system for investigating the contribution of iridescence in butterfly ecology, little is known about them. For this reason, the focus of this research is to take advantage of this novel system to understand the influences of genetics and temperature on iridescence through three main questions: 1. What is the variability of iridescence? 2. To what extent do genetic factors influence phenotypic variation? 3. Is structural coloration a phenotypic plastic trait shaped by temperature? To address these questions, a complex rearing system was designed, where fixed pedigree lineages from Parides sesostris butterflies are subjected to different thermal conditions to understand the influence of climate and inheritance on the variability of this trait. The expected outcome is that this remarkable trait exhibits extensive variation after temperature treatments within pedigree lineages, indicating a significant influence of environmental forces on its variability. The anticipated results lay the groundwork for further research, focusing on understanding the dynamics of iridescence in butterflies.

June 19 • 9:05 • Camino de Cruces

The two cryptic species of *Trema micrantha* of Barro Colorado Island: A model for tropical tree speciation?

Presenter: Camila PIZANO

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Trema micrantha (L.) Blume, a light-demanding pioneer tree widely distributed in the Americas, includes four clades, two of which are present in the Barro Colorado Nature Monument (BCNM). Brown *Trema*, which has a brown seed endocarp, occurs mainly on landslides where mineral soil is exposed, and black *Trema*, which has a black endocarp, is found mainly in large treefall gaps in the interior of the forest. In addition to genetic differences, these cryptic species, with long-lasting seeds that remain in soil seed banks, contrast in seed dormancy and germination requirements, seed defenses, and seed-associated fungal communities that affect seed survival and germination. Moreover, field and greenhouse studies have shown that differences in soil abiotic (soil nutrients) and biotic (soil microbes) conditions, as well as herbivores, determine habitat segregation of these species. Thus, phylogenetic and ecological data are key to improving our understanding of how abiotic and biotic habitat variation mediate differentiation among tropical cryptic species.

June 19 • 9:15 • Camino de Cruces

Understanding the value of the forests of the Darien, Panama through the participatory establishment of a permanent forest plot with an Emberá territory

Presenter: Maximiliane JOUSSE

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Forests are essential to stabilizing the earth's climate but are also threatened by climate change, and networks of permanent forest plots are at the forefront of research to document how forests across the world are responding to this change. In this paper we present the first data from 10 hectares of a new 15-hectare permanent forest plot established in Darien, joining the existing network of forest plots in Panama. This plot, established with the full participation of the Embera of the Balsa territory, fills existing gaps in tropical ecological research; namely the fact that most permanent plots are in accessible locations and almost no research is carried out in Indigenous territories. The Darien forest is one of 25 biodiversity hot-spots in the world and part of the second largest intact forest track in tropical America. We compared results from this plot to the existing 55 ForestGEO plots in Panama, including the BCI Forest Dynamic plot, covering a total of 130 ha of forest. Our dataset includes 826 named species and 48749 trees with diameter at breast height (DBH) ≥ 10 cm. We compared tree species composition and conservation value for the different plots. BCI, being the largest permanent plot in Panama and the most studied tropical forest in the world, serves as an important baseline for this comparison. We observe a continuity in tree species across Panama, with 50% of the named species found in the Darien plot also found in BCI. The Darien and Alto Chagres plots are consistently the most diverse plots, characterized in both cases by a high number of singletons. Nonmetric multidimensional scaling clearly highlights the unique tree species composition of the Darien plot. The large number of morphospecies species and dominance of a reduced number of specific families found in the Darien plot are coherent with Gentry's expectations for the Choco Darien Ecoregion. The high conservation value of the Darien plot is driven by the high number of IUCN data deficient and unidentified species. With 292 species ≥ 10 cm in its first 10 hectares, the Darien plot is developing the most comprehensive data base on this important biodiversity hot-spot.

June 19 • 9:25 • Camino de Cruces

Fallen angels: Epiphyte's struggle for survival from the understory of a rainforest in Panamá

Presenter: Mateo FERNANDEZ LUCERO

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Mateo FERNANDEZ LUCERO, Erik JANNER, and Gerhard ZOTZ

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There are only four studies on the fate of fallen epiphytes (FE), even though falling due to mechanical failures may be the main cause of epiphyte's mortality. The aim of this research is to elucidate the importance of FE for community dynamics, deepening the understanding of: 1. The falling process itself and 2. Post-fall performance. A unique feature of this study is that a concurrent census determines the composition of the epiphytes community on the trees.

Monthly censuses were conducted at the 1-ha. permanent epiphyte plot of San Lorenzo National Park (Colón, Panamá). The forest understory was screened for FE, noting attachment to substrate, vitality, growth, size, phenology, height etc. Survival analysis was used to test the influence of these variables on performance.

A total of 588 individuals (74 spp./12 fam.) were found in 1.25 years. Annually, c. 3-4 % of the canopy individuals (60 % of the spp) fell down, with a death rate of 62%/year. The most common taxa were *N. crassifolium, S. behrii, S. prolifera, D. panamense* and *C. sessiliflora* / Orchidaceae, Polypodiaceae and Araceae, respectively. Over 85% of the individuals fell with a substrate, suggesting mechanical "failures" of the host as the main cause of fall. Survival probabilities increased with plant and substrate size, no contact with soil or litter fall cover. Falling from the host usually represents a "quick" death (≈127,51 Days). However, some genera (e.g., *Anthurium*, *Scaphyglottis*, *Peperomia*) where able to bloom from the understory, potentially contributing to the population even after the fall.

June 19 • 9:35 • Camino de Cruces

Tempo and mode in secondary succession: Changes of aboveground biomass in Coiba Island, Panama

Presenter: Edgardo I. GARRIDO-PEREZ

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Not all secondary forests mitigate Climate Change by capturing CO2 evenly: it depends on land-use history. We reconstructed the land-use histories of nine stands while measuring the diameters and quantifying the Above-Graound Biomass (AGB) for all trees ≥10cm diameter at breast height by combining: participatory observation, walk in the woods, interviews, satellite imagery, and historical-photographical records. Control 1 was a ≥500y-old, virtually never-used forest; control 2 was a still-in-use garden (1919-present). We ordered all seven experimental plots from the highest to the lowest AGB within a land-use gradient which extremes were Controls 1 and 2. The plot on fertile, alluvial soil receiving sawdust had the highest AGB despite recurrent weeding, soil compaction, and isolation from old-grown forest. The 51y-abandoned, unfinished aircraft field (removed soil) had ~zero AGB. A plot averaging 2.03km away of the mature forest, used for meadow (with large, remnant-and-planted fruit, and shade trees), and moderately fertilized with blood and other fluids (it was an abattoir: 1982-1990) had higher AGB compared to all other 33y-old forests. This includes a meadow where reforestation-and citrus monoculture without remnant trees were made (1982-1990). An abandoned Bakery-Rooster's fighting-arena had the fourth highest AGB by combining ~60% of its perimeter in contact with mature forest, with moderate addition of roosters' manure and men urine ~every Sunday. Abandoned tannery kept old forest's trees and fruit trees were added, yet its ~85% ground-cementation resulted in comparatively low AGB. Control 2 planted and protected many avocados, mango, citrus, guanabana, coconut, and some reforestation trees were planted and cultivated resulting in high AGB and trees thicker than mature forest. Among-stands AGB change followed a clear trend line (R2=0.48) suggesting a land-use history-determined gradient of CO2 capture. Three successional pathways emerged from an abandoned pasture, four were related to one river and a camp, another derived from shifting agriculture, and another directly from a >400y-old forest existing in 1919. Many tree-species were human-dispersed. Our results and approach clarify major discussions like the intermediate peak, convergence-vs-divergence, organismic-vs-individualistic, and chance-vs-determinism in Ecology and provide practical, cheap guidance for conservation.

June 19 • 9:40 • Camino de Cruces

Variation in root water storage capacity among tropical trees

Presenter: Brett T. WOLFE

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Tropical trees use vast amounts of water. Most of this passes from roots through leaves in the transpiration stream, but some is stored within tissues for varying durations. Stored water serves to increase gas exchange, enable growth when soil water is not available, and buffer against dehydration during droughts. Among trees, stem water storage capacity has been studied extensively, while root water storage capacity is poorly understood. Among species, stem water storage capacity declines as wood density increases. I measured root water storage capacity in nine tree species on BCI to test whether the same relationship with wood density holds in roots and whether stem water storage capacity can be used to predict root water storage capacity. Roots and stems share the same relationship between wood density and water storage capacity. However, because wood density varies between stems and roots within species, stem water storage capacity is a poor predictor of root water storage capacity. Hydraulic models that incorporate stored water to predict transpiration, phenology, and drought performance can be improved by accounting for the mismatch between stem and root water storage capacity.

June 19 • 9:45 • Camino de Cruces

Biogeochemical processes in Lutz Creek and Conrad Trail Stream, Barro Colorado Island

Presenter: Robert F. STALLARD

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The biogeochemistry of weathering and erosion on Barro Colorado Island (BCI) has been characterized using chemical and sediment sampling, from 1991-2005, of Lutz Creek, the Conrad Trail stream, rainfall, thoughfall, zero-tension lysimeters, and overland flow. One of the main objectives is to compare weathering and erosion in the relatively flat Conrad Trail stream catchment (transport-limited erosion regime) with the same processes in the steep catchments of Lutz Creek (weathering- or supply-limited erosion regime). Substantial groundwater losses from both catchments made the comparison more difficult. Atmospheric inputs deposited on BCI ecosystems or fixed directly by biologic or abiologic processes and then exported in streams are large. The local cycling of bioactive constituents such as potassium, phosphate, and nitrogen compounds is so pronounced that local atmospheric loadings of these bear little relation to the external supply from long-range transport and are therefore more interesting in estimating the supply of nutrients to tree-fall gaps, landslide scars, and small anthropogenic clearings. The contrast between Lutz Creek catchment as an example of a weathering-limited (supply-limited) erosion regime and the Conrad Trail stream as an example of a transport-limited erosion regime is quite marked. Denudation rates calculated for Lutz Creek catchment are approximately 2,000 Mg/km2yr or 780 mm/kyr. Transport-limited erosion is much slower, and denudation rates calculated for the Conrad Trail stream catchment are 30 Mg/km2yr or 17 mm/kyr. Basically, BCI is eroding from the sides and not off the plateau on top. The composition of stream waters and sediments is consistent with these two regimes.

June 19 • 10:30 • Gamboa Grand Ballroom

Effects of insect herbivores and plant pathogens on plant diversity and density dependence across a tropical precipitation gradient

Presenter: Owen T. LEWIS

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Owen T. LEWIS[1], Lars J. MARKESTEIJN[2,3], and Robert BAGCHI[4]

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There is growing evidence that natural enemies of plants, such as fungal pathogens and insect herbivores, contribute to plant species coexistence and diversity in tropical forests by driving negative conspecific density dependence. Plant diversity generally increases with precipitation, and precipitation is also known to influence the activity and impact of both insects and fungi. Thus, increased natural enemy control of plant populations in wet climates could contribute to the relationship between plant diversity and precipitation at a range of spatial scales. We tested this hypothesis at the regional scale by suppressing insects and pathogens with insecticides and fungicides for 18 months at eight sites spanning the steep precipitation gradient across the Isthmus of Panama. We quantified the effect of biocides on changes in diversity during the transition from seeds to seedlings and the relationship between conspecific seed density and the probability of transition from seeds to seedlings (i.e., conspecific density dependence). We found a greater increase in diversity at the seed-to-seedling transition at wet sites; this pattern was weakened by fungicide and insecticide treatments. Conspecific negative density dependence was ubiquitous, but its strength was not correlated with rainfall; nor did fungicide and insecticide treatment significantly affect the strength of density dependence measured in our experiment. In combination with other recent research on plants and their natural enemies, these results suggest that conspecific density dependence imposed on plant populations by their natural enemies strengthens with precipitation, and imply that variation in a coexistence mechanism acting at local scales could contribute to regional patterns in plant diversity.

June 19 • 10:40 • Gamboa Grand Ballroom

Patterns in foliar disease incidence in the tree seedling community across the precipitation gradient in Panama

Presenter: Valerie R. MILICIS

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Many studies have identified fungal and oomycete phytopathogens (hereafter pathogens) as natural enemies capable of contributing to plant community composition. However, variation in the strength of pathogen regulation of plant communities across environmental gradients is poorly understood. Moisture gradients may be of particular interest for study because both plant and pathogen biology are sensitive to moisture availability, which may create variation in the effects of plant-pathogen interactions on community assembly. To evaluate this hypothesis, we surveyed 10,756 seedlings from 272 tree species for disease symptoms along a mean annual precipitation gradient in the forests of Central Panama for three months in the early wet season (June – August) and two months in the following dry season (March - April). Observable disease was rare, only 3% of seedlings were symptomatic of disease, and overwhelmingly owed to necrotrophic foliar pathogens (> 99% of symptomatic seedlings). Foliar disease incidence was sensitive to the moisture gradient and decreased with increasing mean annual precipitation. Disease incidence was non-random, and positively related to conspecific seedling density, although this density-dependent effect was not sensitive to moisture variation. Overall, we find that foliar pathogens may contribute to community composition if density-dependent disease incidence translates to mortality differences, and that this relationship is not affected by the precipitation gradient. Differences in disease susceptibility among the plant communities across the precipitation gradient may explain why disease incidence is highest in the driest forests.

June 19 • 10:50 • Gamboa Grand Ballroom

Ecometabolomics, environmental gradients and the growth-defense trade-off in tropical trees

Presenter: Dale L. FORRISTER

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It has long been hypothesized that the intensity of biotic interactions increases towards the equator and in warmer and wetter environments. A key prediction of this hypothesis is that investment in plant defenses increases in response to increased pest pressure because plants optimize their relative investment in defense and growth as a function of available resources and enemy pressure. In this talk, I will discuss how we can leverage untargeted metabolomics, high throughput antifungal and antiherbivore bioassays, alongside data from forest dynamics plots to test the prediction that species adapted to warmer and wetter environments invest more in defense. In doing so we ask how a plant's metabolome changes across the strong precipitation and phosphorous gradients located in central Panama. We also consider how metabolomes change along two key ecological tradeoffs the interspecific growth–mortality trade-off, associated with a species' shade-tolerance, and stature-fecundity tradeoff. By integrating untargeted metabolomics with bioassays, we seek to test the functional significance of observed changes in a species metabolome in response to these ecological gradients.

June 19 • 11:00 • Gamboa Grand Ballroom

Plant metabolites contribute to density-dependent performance, and hence niche partitioning, within communities and reflect clines in abiotic and biotic selection over environmental gradients

Presenter: Brian E. SEDIO

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Brian E. SEDIO[1,2], Sierra CHADWICK[1], David HENDERSON[3], Edwin LEBRIJA-TEJOS[2,4], Martin VOLF[5], S. Joseph WRIGHT[2], Sebastián TELLO[6], and Jonathan A. MYERS[3]

1. University of Texas at Austin. 2. Smithsonian Tropical Research Institute. 3. Washington University in St. Louis. 4. University of Haifa. 5. Czech Academy of Sciences. 6. Missouri Botanical Garden

Fundamental hypotheses concerning the maintenance and generation of diversity in ecological communities posit a central role for the differences among plants in metabolites that function as defenses against herbivores and pathogens. Yet the vast diversity of plant chemical defenses has traditionally precluded community-level studies of chemical ecology. Here, we use untargeted metabolomics based on mass spectrometry to identify, classify, and compare the structures of >10,000 unique foliar metabolites from 314 tree species recorded in the BCI 50-ha forest dynamics plot and >20,000 metabolites from 906 species sampled in 16 1-ha forest plots representing an elevational gradient in the tropical Andes in Bolivia. We ask whether species metabolomes define niches by i) contributing to density-dependent mortality driven by enemy-mediated competition and ii) varying over elevational and environmental gradients. We find that seedling survival is reduced by heterospecific neighbors that are similar with respect to secondary metabolites, but enhanced by similarity to primary metabolites on BCI. Further, chemical dissimilarity of co-occurring species declines with elevation but increases with species diversity in the tropical Andes, whereas chemical properties associated with light absorptance, polarity, and topological complexity, vary in ways that suggest variation in the sources of selection on plant metabolomes over elevational gradients.

June 19 • 11:10 • Gamboa Grand Ballroom

Exploring latitudinal trends in plant-insect interactions and plant specialized metabolites

Presenter: Martin VOLF

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Most multicellular terrestrial organisms are either invertebrates or plants, with the diversity of the two being closely linked in many ecosystems. To explore this link, we sampled 0.1 ha forest plots worldwide, including Panama's San Lorenzo site, for arthropods, woody plants above 5 cm DBH, and their interactions. Our findings reveal that the latitudinal gradient in plant diversity correlates with the species richness gradient of leaf-mining insect communities, but not ants, which should exhibit greater diversity in temperate forests. Our ongoing projects aim to connect trends in plant-insect interactions to plant functional diversity and the diversity of specialized metabolites in particular. Our findings from temperate regions suggest that shifts in the significance of stress caused by specialized insect herbivores and abiotic conditions drive distinct phylogenetic trends in plant chemistry, supporting varied dimensions of chemical diversity. We propose that similar stress gradients may underlie global trends in metabolite diversity. Abiotic stress may support a directional phylogenetic increase in metabolite concentration and selects for convergent chemical traits among plant species. Conversely, under pressure from specialized enemies, plants may be selected to switch to alternative defense strategies rather than investing in the richness or concentration of their current metabolites, supporting chemical divergence and chemical variation between the species. To test these hypotheses, we compared temperate datasets with diverse genera of tropical trees from Papua New Guinea. We now propose a global project, including BCI as one of the focal sites, to investigate factors driving the remarkable diversity of plant metabolites. Ultimately, we aim to utilize this data to elucidate global shifts in plant chemical strategies and their effects on interactions with insect herbivores.

June 19 • 11:20 • Gamboa Grand Ballroom

Escaping the enemy: Spatial ecology of plant-insect interactions in tropical forests

Presenter: Patrick G CANNON

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Ecological theory posits that specialized natural enemies contribute to the extraordinary plant diversity of tropical forests by eliciting strong negative density-dependent recruitment. Whilst the majority of past research has focused on seeds and seedlings post-dispersal, highly host-specific seed feeding insects cause a significant proportion of seed mortality in the canopies of many tropical trees. If predation rates are dependent on the surrounding densities of conspecific trees, pre-dispersal insect seed predation may represent an important and critically understudied mechanism contributing to high local tree diversity in tropical forests. To examine the potential for density-dependent rates of insect seed predation, we utilize remote sensing imagery to map reproductive individuals of a handful of canopy tree species across BCI, and rear insects from corresponding fruit collections. Our work represents a novel scale for examining the role of density-dependence in maintaining tropical plant diversity, with potential implications for later stages of plant recruitment.

June 19 • 11:30 • Gamboa Grand Ballroom

Seedling insect herbivory along succession in a Neotropical forest

Presenter: Damla CINOĞLU

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The majority of tropical forests have been subject to human disturbances, resulting in successional communities of varying forest ages. Insect herbivores play a key role in shaping the composition and diversity of tropical tree communities. Changes in abiotic conditions, namely understory light availability, along with shifts in the ecological strategies of dominant plant groups or changes in insect communities, might result in differences in insect herbivory across forest succession. However, we have a limited understanding of how insect herbivory is altered in secondary forests, and how insect herbivory varies within and among groups of plant species that differ in their ecological strategies. We hypothesized (1) herbivory to be higher in older forests compared to younger forests, and (2) fast growing tree species to have significantly higher herbivory than species with other ecological strategies.

To test these hypotheses, we measured leaf herbivory damage on 5021 woody seedlings of 213 species in forests along a chronosequence in Panama. Specifically, we quantified individual-level percent herbivore damage and measured understory light availability for 1526 1x1m seedling subplots within 10 1-ha plots spanning a successional gradient from <20 to 128 years since disturbance.

Consistent with our first hypothesis, we found that forest age was significantly positively correlated with herbivory. Interestingly, understory light availability did not explain independent or additional variation in herbivory. Mean herbivory was significantly higher for fast growing species compared to slow growing species and long-lived pioneers. We found fast growing species experienced significantly more herbivory in late successional forests than in early successional forests. This research contributes to our understanding of how past human disturbance impacts natural enemy pressure on tree seedlings, which may influence successional dynamics and diversity in tropical forests.

June 19 • 11:40 • Gamboa Grand Ballroom

Effects of natural enemies on seedling community dynamics during the secondary succession of Panamanian rainforests

Presenter: Anita WEISSFLOG

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Insect herbivores and fungal pathogens alter seedling performance, abundance, and diversity in mature forests. Their role in secondary succession, i.e., rainforest recovery, remains however understudied. Interactions between plants and their natural enemies could drive successional shifts in seedling community composition if they vary with plant functional type (PFT) and species' local abundance or favor unrelated successors. We present two research projects on the impact of natural enemies on successional seedling community dynamics across two Panamanian chronosequences.

First, we conducted greenhouse experiments to assess how soil successional age (0-,15-,25-,115-yrs) affects fungal-mediated plant-soil feedbacks (PSF) on germination and survival of seven tree species. Tree species varied in their association from early- to late-successional forests and their phylogenetic distance to eachother.
We found lower susceptibility of late-successional species, suggesting a potential decrease in importance of PSFs with increased forest age. Overall, species experienced more positive PSF in soil ages at which they peak in abundance, indicating that species-specific mutualists promote establishment of species at their associated successional stages, potentially slowing down successional turnover. Negative heterospecific PSF decreased with phylogenetic distance, favoring unrelated successors and possibly accelerating diversification.

Second, an ongoing field experiment explores the effect of insects and fungi on seedling communities in seven forests regrowing for 9, 49, 69, or 99 years. In each forest, three treatments (insecticide, fungicide, water-sprayed control) are applied to 26 1m2 plots each. All woody seedlings (5-130 cm) are identified to species level and grouped into PFT based on growth form (tree, liana) and demographic strategy. We monitor seedling survival and growth biannually for two years.

Integrating findings of our greenhouse and field studies will advance our understanding of successional and PFT-specific variation in the effects of natural enemies on seedling communities, which play a crucial role in shaping future forest composition and diversity.

June 19 • 11:50 • Gamboa Grand Ballroom

The interplay between defaunation and phylogenetic diversity affects leaf damage by natural enemies in tropical plants

Presenter: Carine EMER

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Natural enemies play an important role in controlling plant population growth and vegetation dynamics. Tropical rainforests host the greatest herbivores diversity, from large mammalian ungulates to microscopic pathogens, generating and maintaining plant diversity. By feeding on the same resources, large mammalian herbivores may interfere with plant consumption and leaf damage by important enemy guilds such as invertebrate herbivores and pathogens, triggering indirect trophic cascades. However, the impact of local extinctions of large herbivores on plant–enemy interactions is relatively unknown. We experimentally tested the effects of defaunation of large mammalian herbivores (e.g. peccaries, tapirs and brocket deer) on the leaf damage of 3350 understorey plants in tropical rainforests of Brazil. We examined leaf damage in 10,050 leaves from 333 morphospecies by assigning the area consumed/damaged by five guilds of insect herbivores and leaf pathogens within 86 open-closed plots and investigating the joint effects of defaunation and plant phylogenetic diversity. Plants released from large herbivores had 9% less leaf damage; this difference was due to the lower leaf pathogens incidence (29%) rather than insect herbivory. Evolutionary distinctness was positively correlated with leaf damage across treatments, suggesting additive effects of defaunation and phylogenetic diversity. Total and pathogenic leaf damage (but not insect damage) decreased with plant richness across treatments, and large herbivores exclusion resulted in increased plant species richness. This suggests that large herbivores exclusion leads to a dilution of total and pathogens' leaf damage by increasing plant species richness. Our results suggest that large herbivores' indirect effects decrease the dilution potential of plant communities against pathogens and reinforce their top-down impact on vegetation, demonstrating a previously overlooked cascading effect on forest ecosystems.enemies on seedling communities, which play a crucial role in shaping future forest composition and diversity.

June 19 • 10:30 • Camino de Cruces

Agua Salud: Sustainability science for the 21st century

Presenter: Jefferson Scott Hall

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Jefferson S. HALL

ForestGEO, Smithsonian Tropical Research Institute

Sustainability requires evidence-based policy. Moving science to policy and practice is hard. Doing so in a timely manner, that meets the moment of urgent need to take actions addressing global change, requires a multidisciplinary and integrated approach to the practice of science.

The Agua Salud Project studies the ecosystem services provided by tropical forests and how they change with land use and climate change. The project leverages basic, use-inspired, and applied research as well as natural history observations to address broad questions related to sustainable management of tropical lands. This requires researchers to go beyond the relatively simple, but by no means trivial, step of measuring ecosystem services to initiate studies of ecosystem function and social systems to assist in the development of the next generation of models that project and secure services in an uncertain future.

Our work has been possible only with the collaboration of partner institutions, including universities and implementing institutions. Partnerships complement STRI strengths and have helped foster ownership thus facilitating implementation, with collaborations helping to extend research applications far beyond our research base in Panama.

This talk will introduce the Agua Salud Project research platform and conceptual model. As the opening talk to the oral session, it will provide the framework for subsequent talks illustrating Agua Salud's multidisciplinary approach to truncating the time required to undertake research and effect policy and practice.

June 19 • 10:40 • Camino de Cruces

Feedback loops drive ecological succession: Towards a unified conceptual framework

Presenter: Michiel VAN BREUGEL

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Michiel VAN BREUGEL[1,2,3]

1. National University of Singapore, Department of Geography. 2. Yale-NUS College, Singapore. 3. Smithsonian Tropical Research Institute

The core principle shared by most theories and models of succession is that, following a major disturbance, plant–environment (PE) feedback dynamics drive a directional change in the plant community. The most studied PE loops are those in which the regrowth of the plant community causes changes to the abiotic or biotic environment, which differentially affect species availability or performance, which, in turn, leads to shifts in the species composition of the plant community. While PE feedback loops in principle generate predictable successional trajectories, succession is generally observed to be highly variable, which is driven by the stochastic processes involved in the PE feedback dynamics and by extrinsic causes of succession. Both can lead to variation in the identity of dominant species within communities and consequently to priority effects. Predictability and variability are thus intrinsically linked features of ecological succession.

I present a new conceptual framework of ecological succession that integrates the propositions discussed above. This framework defines general causes that, when involved in a feedback loop, drive succession and when not, create variability in successional trajectories. The proposed framework provides a guide for linking these general causes into causal pathways that represent specific models of succession. To illustrate how the framework can be used, I identify and compare the causal pathways that represent the actual empirical studies of Agua Salud's long-term secondary forest dynamics project with the causal pathways that represent the project's underlying conceptual ideas. The differences between these causal pathways highlight the need to move beyond the conceptual models that currently dominate in our field and to find ways to examine the relative importance of and interactions among alternative causal pathways of succession.

June 19 • 10:50 • Camino de Cruces

Tropical forest carbon sequestration accelerated by nutrients

Presenter: Wenguang TANG

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Wenguang TANG[1], Jefferson S. HALL[2], Oliver L. PHILLIPS[1], Roel J. W. BRIENEN[1], S. Joseph WRIGHT[3], Michelle WONG[4,5], Lars O. HEDIN[6], Michiel VAN BREUGEL[2,7,8], Phillip M. HANNAM[4], and Sarah A. BATTERMAN[1,3,4]

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Identifying the factors that regulate tropical forests' carbon sequestration is crucial for predicting and managing the future tropical carbon sink. Theory suggests that nutrients, especially nitrogen and phosphorus, can constrain tropical forest carbon accumulation, but we lack empirical evidence for whether and how nutrients influence the carbon sink over the course of forest succession. Here we document how carbon accumulation responds to a factorial nutrient manipulation in 76 experimental plots across a large tropical forest landscape in different stages of secondary succession. Our experiment is the first to demonstrate a shift in nutrient limitation on biomass accumulation over forest succession, from strong nitrogen limitation in young forests, when carbon accumulation is the highest, to no evidence of nutrient limitation in mature forests. The addition of nitrogen led to a 95% increase in net biomass accumulation in the first few years of forest recovery. Contrary to prevailing biogeochemical theory, we observed no influence of phosphorus on biomass accumulation at any stage. Our findings help inform efforts for reforestation and predicting nutrient effects on the future tropical forest carbon sink in the face of climate change.

June 19 • 11:00 • Camino de Cruces

Changes in soil microbial diversity with nutrient addition in a rapidly growing tropical forest

Presenter: Kristin SALTONSTALL

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Kristin SALTONSTALL[1], Sarah BATTERMAN[1,2], Michiel VAN BREUGEL[1,3], Miguel NUÑEZ[1], Michelle WONG[1,4], Lars HEDIN[5], and Jefferson S. HALL[1]

1. Smithsonian Tropical Research Institute. 2. Cary Institute. 3. National University of Singapore. 4. Yale University. 5. Princeton University

Forest recovery following abandonment of agricultural lands in the tropics depends on a variety of factors, including the surrounding vegetation communities, levels of soil degradation, and natural disturbance processes. Belowground microbial communities may also play an important role in the recovery of forest communities, as microbes may either enhance or delay forest recovery. However, the environmental factors controlling soil microbial communities along resource gradients remain poorly understood in tropical forests, particularly in early-successional habitats. We are working in the fully factorial N and P addition experiment that includes early successional forests of three ages (0, 8-12 years, and 26 yrs) in the Agua Salud landscape in the province of Colón, Panama to evaluate the role of nutrients in driving microbial community succession. We sampled soils prior to the initiation of nutrient treatments, and one and four years after treatments began and investigated changes in soil bacterial and fungal communities across forest ages and over the four year period by sequencing 16S and ITS metagenomic libraries on an Illumina MiSeq. Other edaphic factors, such as pH and soil fertility, of each soil sample, as well as aboveground vegetation cover at each site were also analyzed as other properties of the landscape may also drive community changes. Given other work that demonstrates relationships between nutrients and microbial community composition, we hypothesize that nutrient additions will lead to differences in microbial community composition between treatments, but that within treatments, these communities will also differ across forest age classes. Such detailed analyses of soil properties and vegetation cover will enhance our understanding of the role that soil microbial communities may play in successional processes of tropical forests.

June 19 • 11:10 • Camino de Cruces

Arbuscular mycorrhiza in native timber plantations in the Panama Canal watershed

Presenter: Raquel M. RODRÍGUEZ-RODRÍGUEZ

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Kristin SALTONSTALL[1] and Jefferson S. HALL[1]

1. Smithsonian Tropical Research Institute

Native timber plantations can optimize reforestation efforts by enhancing both ecosystem services and economic returns in degraded tropical landscapes. Interactions with soil microorganisms, such as arbuscular mycorrhizal (AM) fungi are key to establishing and maintaining plant communities in tropical forests. We worked in the fully replicated plantation system at the Agua Salud Project in the central basin of the Panama to characterize variation in the communities of AM fungi in soil and their interactions with plants, focusing on *Terminalia amazonia* planted in monoculture and mixtures with other four native timber species (*Anacardium excelsium, Dalbergia retusa, Pachira quinata*, and *Tabebuia rosea*). We assessed major AM attributes (spore density, mycorrhizal colonization, inoculum potential and soil AM fungal diversity), and soil properties in the dry (January, April) and rainy (July and October) seasons in 2023. Using DNA metabarcoding, we also characterized the diversity and composition of AM communities in the soil and how these communities change throughout the year. Plots in secondary forest, mature forest and *Tectona grandis* (teak) plantations were also included as references. Preliminary analysis suggests that both monoculture and mixed species *T. amazonia* plantations harbor similar densities and activity of AM fungal communities as secondary forests, while *T. grandis* plantations present lower AM densities and activity.

June 19 • 11:20 • Camino de Cruces

Assessment of ground-dwelling mammals on timber plantations embedded in the landscape mosaic of Central Panama

Presenter: Claudio Manuel MONTEZA-MORENO

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Claudio M. MONTEZA-MORENO[1,2,3*], Mark N. GROTE[4], Jefferson S. HALL[2], and Patrick A. JANSEN[2,5]

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Timber plantations are commonly use in reforestation projects in the tropics. However, because timber plantations often consist of monocultures of non-native timber species, it is not clear whether such plantations contribute to the recovery of biological diversity and empirical evidence is still scarce. Here, we evaluate ground-dwelling mammal species diversity and their intensities of use in a fine-scale mosaic of timber plantations in Central Panama, the narrowest tract of the Mesoamerican Biological Corridor. We deployed camera traps at stratified random points and followed a hierarchical-modeling approach to compare species richness and their occupancy between plantation types. We recorded 16 ground-dwelling mammals among the five timber plantations. The majority of the species were small-bodied and short-lived, and their occupancy probabilities were below 0.5 at any given plantation. Teak (*Tectona grandis*) plantations, which covered the largest area in the study, had the lowest estimated richness and occupancy, with occupancy probabilities exceeding 0.5 for just three species. In contrast, plantations of the native *Pachira quinata* and the non-native *Gmelina arborea*, covering an area four and nineteen times smaller than Teak, respectively, had higher richness and occupancy. Occupancy values were intermediate in the Acacia and Mixed plantation types. Our results suggest that plantations embedded in lowland tropical landscapes have limited conservation value for large-bodied mammals, and are ecologically constrained habitats for small and medium-sized mammals.

June 19 • 11:30 • Camino de Cruces

Contributions of Agua Salud catchment scale experiments to understanding tropical forest hydrologic ecosystem services – Past findings and future directions

Presenter: Melinda D. DANIELS

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Melinda D. DANIELS[1], Jefferson S. HALL[2], Diana OVIEDO-VARGAS[1], and Marc PEIPOCH[1]

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Tropical watersheds provide critical freshwater ecosystem services that sustain livelihoods and ensure the well-being of nearly three billion people globally, including the provision of clean water for drinking, agriculture and industry, energy production, recreation, tourism, transport and trade. To ensure the sustainable provision of these ecosystem services, it is vital that we understand to what extent tropical forests regulate water flows and influence water quality, and how these dynamics change with land use and climate change. The Agua Salud project represents a critically important opportunity to address these questions, possessing an infrastructure of similar quality to the most advanced experimental watersheds in the temperate zone. Previous investigations have already contributed significant advancements to our understanding of the role of land use in modifying watershed hydrologic dynamics in response to seasonal and event precipitation inputs, finding evidence that forest cover reduced peak storm runoff as well as total storm runoff, yet increased streamflow during dry periods, supporting the “sponge effect” hypothesis. We plan to continue these investigations to more closely assess fundamental process relationships between land cover and watershed hydrologic response as well as the temporal aspect of these changes as watershed land covers mature. By continuing this important work, in the future we can begin to develop models of how land management can affect the provision of freshwater ecosystem services and better understand and predict how global climate change may alter the provision of these services.

June 19 • 11:40 • Camino de Cruces

Citizen science watershed resilience: Studentand teacher-led exploration of land use change and stream health

Presenter: Andrea F MILLER

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Andrea F Miller[1], Jefferson Scott HALL[2], Debra L. S. PSYCHOYOS[3], Ummat SOMJEE[4], Jorge BATISTA[5], Jimena J. PITTY[6], and Katherine SINACORE[7]

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Access to clean and safe water is one of the most pressing challenges of the 21st century. Over 2.4 billion individuals worldwide reside in water-stressed countries. As climate change further drives the unpredictability of water availability in many regions, particularly in the tropics, land use change and development further threaten not only the abundance, but also the quality of our water sources. While research suggests that forests play a pivotal 'sponge-effect' role in both mitigating the impacts of flooding and replenishing rivers during drier periods, forests have also been associated with higher stream health. Conversely, land practices that involve deforestation, such as cattle ranching and urban development, tend to produce precisely the opposite outcomes, adversely impacting water quality and quantity.

Despite this evidence of this link, few communities have the resources to test the relationships between land-use and water quality. One of the main obstacles is that most water monitoring equipment is prohibitively costly and difficult to implement, making it impractical for communities and for larger scale monitoring programs. Even though scientists share data, it is often inaccessible to communities (e.g. behind paywalls) or is difficult to interpret, and rarely are findings incorporated into the educational systems. The absence of robust, easily accessible, community-owned data, coupled with the lack of feedback loops into education, stifles the ability of local communities to make informed water management decisions collectively.

"Citizen science watershed resilience: student and teacher-led exploration of land use change and stream health" centers on establishing a robust citizen science project, integrated into the education system, that is designed to quantify stream flow and water quality of the community's riverways. We aim to employ cost-effective and well-established methodologies, paired with training teachers to incorporate citizen science into their core curriculums and objectives. One major objective is to train future leaders in regenerative decision making by cultivating pride in the community's role in both local, regional and global water resilience.

June 19 • 11:50 • Camino de Cruces

Local socioeconomic dynamics, governance and perceptions regarding the Rohr Reforestation Initiative in the Comarca Ngäbe-Buglé

Presenter: Jazmín GONZALES TOVAR

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Jazmín GONZALES TOVAR[1,2], Karen CÁRDENAS[2], Daniel HOLNESS[3], Francisco HERRERA[3], Dilcia MITRE[3], Jefferson HALL[2], and Reem HAJJAR[1]

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Forest restoration has gained wide popularity across the tropics as a way to mitigate climate change. In 2022, the Smithsonian Tropical Research Institute (STRI) signed a 20-year agreement with the Traditional Congress of the Ngäbe-Buglé Comarca to carry out an ecological reforestation initiative ("Rohr Reforestation Initiative", RRI) with the goal of advancing restoration science while engaging and benefiting impoverished communities. While our understanding of the biophysical aspects of tropical forest restoration has made many advances in the past decades, restoration social science – the understanding of policies, politics, user norms and attitudes, and their interactions with local livelihoods related to restoring ecosystems – is a relatively understudied field. Recent global analyses have highlighted the need to respect local and traditional land rights, as well as consider equity issues, in assessing sites suitable for restoration. Others have reviewed the impacts of migration and land use on restoration, the cost-effectiveness of scaling smallholder restoration, and factors that lead to more successful restoration outcomes. Yet research linking forest restoration to social, political, or economic outcomes has been limited. Better understanding governance systems and resource user groups, as well as the impacts of interventions on these is crucial for adaptive management and learning in this complex social-ecological system. This study uses quantitative methods to (i) develop a baseline of local socioeconomic conditions and governance mechanisms; (ii) capture local perceptions on the RRI initiative regarding (des) motivations and perceived opportunity-costs. To do so, a simple household survey is applied to representatives of households located in the district of Ñurum of the Ngäbe-Buglé Comarca, including all current (n=28) and previous (n=5) beneficiaries of the reforestation initiative as well as a random sample of non-beneficiaries (n=50). The ultimate aim is to help monitor and improve the socioeconomic aspects of the RRI initiative, ensuring its success and longevity, and contributing to a better understanding of the field of restoration social science. Results are relevant for Panama and the tropics as a whole.

June 19 • 10:30 • Las Jacarandas

Interacciones entre grupos humanos y el paisaje en Panamá durante el Holoceno medio y tardío a través del estudio de las materias primas líticas y el análisis de huellas de uso: Retos y perspectivas a futuro

Presenter: Arturo GARCÍA DE LEÓN

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Las herramientas líticas son uno de los materiales culturales más comunes en los yacimientos arqueológicos. El análisis de las concentraciones líticas ofrece información valiosa sobre las adaptaciones humanas y la organización socioeconómica dentro de condiciones ambientales específicas. En el caso del Istmo de Panamá, la evidencia arqueológica ha demostrado que los grupos humanos ocuparon por primera vez el Istmo hace al menos 11.000 años. Durante el Holoceno, en sitios costeros y de bosques tropicales, se han documentado diferentes organizaciones socioeconómicas, basadas en la variabilidad de la elección de materias primas y en la manufactura de herramientas líticas. Sin embargo, todavía existe un gran desconocimiento sobre la relación entre la tecnología lítica y el medio ambiente. Este proyecto pretende reconstruir las elecciones tecnológicas de las comunidades Indígenas para comprender mejor las interacciones entre el humanos y el paisaje durante el Holoceno medio y el Holoceno tardío. El proyecto se divide en tres etapas de investigación:
1) La primera prospección extensiva de materias primas líticas para muestrear la variabilidad alrededor de los sitios arqueológicos seleccionados donde se han llevado a cabo proyectos arqueológicos (Tierras Altas de Chiriquí, Bahía Parita, Ensenada de Garachiné);
2) Un enfoque multianalítico que incluye arqueología experimental, caracterización petrográfica y geoquímica de la materia prima con el fin de crear una colección de referencia de huellas de uso. Este último, se utilizará para comprender cómo se utilizaban las herramientas.
3) Un estudio en profundidad de dos conjuntos líticos arqueológicos procedentes de diferentes entornos. Estos casos de estudio utilizarán la colección de referencia y se aplicarán las mismas técnicas que utilizamos para la elaboración del programa experimental.
Los resultados situarán la tecnología lítica en contextos analíticos más amplios, vinculando los datos paleoecológicos con las interpretaciones socioeconómicas en el istmo de Panamá. Mis resultados constituirán el primer estudio sistemático integrado de huellas de uso en el sur de Centroamérica y sentarán las bases para nuevas investigaciones sobre la procedencia y la tecnología de estos materiales.

June 19 • 10:35 • Las Jacarandas

Panamanian traditional rope-tension drums: A global history of adaptation and resilience in the heart of the tropics

Presenter: Samuel ROBLES

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Panamanian traditional drums, such as the caja santeña and the pujador, are the result of a complex Caribbean history with global ties. Rope-tension drums were developed through centuries of innovation and adaptation: from early examples in southern Asia to contributions of middle-eastern and north-African instrument makers, to European military snare drums. The Swiss Basel-type drum became the standard for European armies and navies, and it is this style of drum –double-headed, with flesh hoop, counterhoops and snares– which meets membranophones developed for centuries by the indigenous peoples of the Americas from the sixteenth century onward. I will discuss the processes through which this multiple origin story coalesced in the Caribbean, particularly in the tropical transit zone between the oceans in the Panamanian Isthmus and rural hinterlands, resulting in adapted rope-tension technology from two-headed drums to single-headed membranophones. I will also show how Panamanian drums and the associated musical-cultural practices embody, reflect, and evolve upon a complex social history, and have furthermore become symbols of resistance both in Panama and in the circum-Caribbean region, particularly for indigenous and Afro-Caribbean social groups. I will conclude with a discussion on how the historical developments of Panamanian drums and drumming have become an integral part of an ongoing identity-building process and cultural re-signification in the Isthmus of Panama.

June 19 • 10:40 • Las Jacarandas

A Pleistocene fossil wood flora from the Gigante Peninsula and comparisons with the modern-day flora

Presenter: Camila MARTÍNEZ

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Camila MARTÍNEZ[1,2], Diana K. PÉREZ-LARA[1,2], David S. AVELLANEDA-JIMÉNEZ[2,3], Oris RODRÍGUEZ-REYES[2,4], José DUQUE[1], and Carlos JARAMILLO[2]

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We described remains of a Pleistocene humid forest based on a permineralized fossil wood assemblage discovered at the Gigante Peninsula, in the Barro Colorado Nature Monument (BCNM), Panama and the nearby area. Sedimentological and stratigraphic analysis suggests that the fossil trees were buried due to volcanic activity. Radiometric analyses of four tuffs associated with the fossils indicate middle to late Pleistocene ages (< 1 Ma). During this time, the Earth's climate was marked by glacial and interglacial oscillations. A total of 224 samples were located and 122 of them were collected and until now 64 have been prepared, described, and assigned to 15 morphotypes. None of the morphotypes found at Gigante Peninsula are shared with those present in the recently described mangrove flora from Barro Colorado Island (Martínez et al., 2024). Comparisons of wood anatomical features with modern wood suggest the presence of the families: Arecaceae, Bignoniaceae, Chrysobalanaceae, Convolvulaceae, Fabaceae, Humiriaceae, Lauraceae, Salicaceae and Phyllanthaceae. The taxonomic composition at the family level is shared with the modern BCNM flora and indicate a closer affinity with humid forests, however, preliminary wood anatomical comparisons show differences some functional characters. Undergoing investigations of this fossiliferous material will allow us to understand more deeply the changes that the BCNM flora has experienced during the Pleistocene and its possible responses to differences in climate. These findings corroborate the high potential of the region for paleobotanical and paleoecological research and the important role of volcanic events in the configuration of modern-day ecosystems.

June 19 • 10:50 • Las Jacarandas

Exploring the Eocene paleobotanical record of Panama

Presenter: Oris RODRIGUEZ REYES

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Uncovering the paleobotanical record of the Paleogene of Central America is important to understand the composition of the earliest forests in the region. The Azuero peninsula in Panama shows paleobotanical richness, where we can find abundant petrified wood, well preserved permineralized seeds, and a few localities with leaf impressions. Most of the studied areas compile fossils from the Santiago Formation (30-23 Ma), but areas exposing Eocene plants are less common and have been scarcely investigated. The Bucaro beach, where the late Eocene-early Miocene Tonosi Formation is exposed, has only been studied by Herrera and collaborators to date. They reported permineralized endocarps collected from this formation of families such as Arecaceae, Vitaceae, Humiriaceae, Anacardiaceae, and Lamiales. We have conducted two projects from 2017 to 2022, aiming to update the geological map of the Azuero Peninsula, through the addition of new geochronological, biostratigraphic, and palynological data and to reconstruct the paleofloristic composition of the forests, based on petrified wood from different geological epochs in the Peninsula. We included a collection of Eocene wood samples for the first time in Panama, which we first attempted to identify using petrographic sections. Preliminary results show the occurrence of Anacardiaceae, Leguminosae and Arecaceae. However, the preservation did not allow a finer identification of the samples. We are adding Scanning Electronic Microscope imaging to support the suggested affinities. The evidence represented in the permineralized endocarps and preliminary identities based on woods suggest a rainforest environment in Panama during the Eocene. With this project, we contribute to the knowledge of the early rainforests of Panama and its geological and paleobiological scenario.

June 19 • 11:00 • Las Jacarandas

Retidiporites magdalenensis: A paleopalynological enigma from the Neotropics and its potential connection to CAM photosynthesis in Bromeliaceae

Presenter: Maurcio LEÓN-CARREÑO

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The Neotropics stands out as the most biodiverse region on Earth, and palynology has contributed significantly to our understanding of the history and evolution of its vegetation. However, taxonomic resolution represents a significant challenge in palynology, limiting our ecological and evolutionary interpretations derived from the fossil record. In the current digital era, the use of high-resolution microscopy and digital image analysis offers the possibility to discriminate pollen types more accurately through detailed morphological measurements. In this context, *Retidiporites magdalenensis*, a Maastrichtian fossil palynomorph found in the Caribbean region, Borneo and Nigeria, remains the subject of uncertainty as to its botanical affinity. Although superficial similarities have been noted with plants in the subfamily Banksioideae of the family Proteaceae, a distinct diporate-reticulate pollen morphology is noted in *R. magdalenensis*, in contrast to Proteaceae. In addition, connections to the family Bromeliaceae, in particular *Bromelia* and *Aechmea*, have been suggested, highlighting significant ecological differences, as these types of bromeliads adapt to water-scarce conditions by adopting CAM photosynthesis. This research raises the possibility that R. magdalenensis represents the oldest pollen fossil of a Bromeliaceae with CAM photosynthesis, highlighting the importance of palynology in understanding the evolution and ecology of the Neotropics.

June 19 • 11:05 • Las Jacarandas

Understanding the Upper Cretaceous tropical seas: A palaeoceanographic study of the epicontinental sea of the Upper Cretaceous of Colombia

Presenter: David Eduardo CARO CARO

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In the Upper Cretaceous, a significant portion of Colombia's territory was covered by an epicontinental sea, which has been a subject of study for nearly a century due to its unique geological characteristics and the lack of direct analogs. The nature of this sea has been a matter of discussion. What was its real structure? What was the bathymetry of the basin and its real slope? Was it a restricted basin? These are some of the questions that remain without a clear answer. To shed some light on this discussion we are studying one locality in central Colombia in what we suppose was the center of the basin, this locality have an approximated age of 75 million years, to understand the bathymetry and oxygenation of this point we have studied the foraminiferal fauna and the geochemistry of these rocks. We have found that the basin in this point had several episodes of low oxygenation alternated with episodes of high concentration of silica and phosphates as well as marked changes in the composition of the foraminiferal fauna showing changes in oxygenation of the benthos and basins depth. Through this analysis, we aim to enhance our understanding of the ancient Colombian epicontinental sea.

June 19 • 11:10 • Las Jacarandas

Sister species an ocean apart: Investigating the drivers of coral reef fish microbiome composition across the Isthmus of Panama

Presenter: Laura L. LARDINOIS

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Three million years ago, the rise of the Isthmus of Panama caused dramatic environmental shifts that set populations of coral reef organisms on separate evolutionary trajectories. Organisms separated by the Isthmus adapted to different environments, forming pairs of sister species. The microbes that interact with these sister species adapted in tandem with their hosts, creating an unparalleled natural experiment to understand the evolution of host-microbe interactions within coral reefs. We investigate the ecological and evolutionary factors driving microbiome composition using seven pairs of sister fish species from Pacific and Atlantic reefs in Panama. Given the importance of the external environment in shaping marine species' surface microbiomes, we expected the fishes skin microbiome to cluster by ocean, whereas the gut microbiome – which has been shown to be influenced by host factors such as diet and phylogeny – would be more strongly driven by host species, such that sister fish gut microbiomes would be more similar than those of distant relatives inhabiting the same ocean. We find evidence for the importance of the host in structuring both skin and gut microbial communities, suggesting long-lasting and important symbioses. However, as predicted, gut microbiomes were more strongly linked to host species than skin microbiomes, likely due to greater host control coupled with the selectivity of the internal gut environment. Gut microbial profiles were more similar across species within dietary strategies (e.g., corallivorous butterflyfishes) and between sister species pairs which indicates that shared host traits play a role in structuring microbiomes. These sister fish species and their unique evolutionary histories are an ideal system to expand our understanding of the drivers underlying coral reef holobionts and, consequently, our ability to protect the diversity of coral reef organisms faced with rapid environmental change.

June 19 • 11:15 • Las Jacarandas

Who, where, when, and why: Elasmobranch diversity across estuaries of the Tropical Eastern Pacific coast of Panama and Costa Rica scrutinized using eDNA

Presenter: Helio QUINTERO ARRIETA

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1. Smithsonian Tropical Research Institute. 2. Universidad Austral de Chile. 3. Universidad Marítima Internacional de Panamá. 4. Universidad Latina de Panamá. 5. AgroParisTech. 6. Universidad Autónoma de Chiriquí. 7. Shark Defenders. 8. Max Planck for Marine Microbiology.

Sharks and rays play a key role in ecosystems. Yet, understanding their diversity and distribution requires considerable time and effort, particularly in areas with low densities due to high fishing pressure or low visibility, such as nearshore mangroves and estuaries, which many sharks and rays use as nurseries. In the Tropical Eastern Pacific, one of the most productive and isolated regions of the oceans, numerous elasmobranchs use these nearshore habitats as breeding grounds as part of their migratory route or use these habitats yearlong; however, the seasonal distribution of sharks and rays in these habitats is not well understood. The study of genetic material released by elasmobranchs in the environment in the form of cells, extracellular DNA, or waste (eDNA) is a powerful approach that allows us to quickly, cost-effectively, and non-invasively detect the presence of organisms, particularly in areas where traditional methods are complex to use at large scale or cannot generate information at the pace needed to support conservation measurement. We aim to describe seasonal changes in the distribution of sharks and rays in 25 estuaries along the Pacific of Panama and Costa Rica. We partnered with artisanal fishermen, local communities, and NGOs to sample 1296 seawater and 492 sediment samples over four sampling seasons. Paired with the samples, we took measurements of dissolved oxygen, salinity, and temperature to determine if these variables are related to organisms' distribution and build niche occupancy models. Finally, we are building a genomic reference database with local samples from bycatch. Sequencing of the 12S ribosomal mitochondrial gene fragment for 349 samples (wet season 2023) shows that the coastal sites in the Gulf of Chiriquí in Panama and Golfo Dulce in Costa Rica have higher elasmobranch species richness, followed closely by Coiba and Golfo de Montijo. The most prevalent species in terms of frequency of detection and read relative abundance is the scalloped hammerhead shark *Sphyrna lewini*. We also detected endemic TEP species like the Pacific eagle ray *Aetobatus laticeps*, Pacific nurse shark *Ginglymostoma cirratum*, Pacific smalltail shark *Carcharhinus cerdale*, Pacific sharpnose shark *Rhizoprionodon longurio*, and the longtail stingray *Hypanus longus*. The taxonomic assignments of most of the endemic species could be refined with the reference sequences of whole mitogenomes from the tissue collection. Our results will be crucial for informing regional conservation by highlighting areas of high diversity (hotspots), identifying areas where highly endangered species occur, and generating predicting species' distribution maps.

June 19 • 11:25 • Las Jacarandas

Novel insights into coral coexistence through early life competition studies - Thanks to vital stains

Presenter: Carrie SIMS

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A premise of species coexistence theory is that conspecifics compete more intensely than heterospecifics, often due to higher niche overlap. Stronger intra-specific competition relative to inter-specific competition prevents any single species from dominating locally, resulting in increased species diversity within the community. The mechanisms by which such processes may maintain high levels of species diversity in coral reefs remains unclear. This is partly due to the challenge of tracking the life stages of multiple coral species concurrently where the potential to promote coexistence is likely to be most pronounced – demographic bottlenecks such as the settlement and early post-settlement life stages.

We focused on this early life stage bottleneck, where density-dependent interactions are considered most likely. By employing a novel vital stain method, we were able to differentiate the species' larvae and recent settlers, by color, with no negative side effects from staining. In an experimental setting, we explored the effects of species diversity and population density within local neighborhoods for two Caribbean coral species: *Colpophyllia natans* and *Pseudodiploria strigosa*.

Our results led to the preliminary calibration of intra-specific and inter-specific density-dependent survivorship responses for two coral species, which we link to differences in conspecific and heterospecific aggregation at settlement. This study is the first to differentiate conspecific and heterospecific effects at settlement and post-settlement phases of corals. The success of our vital stain approach will enable future work calibrating conspecific and heterospecific differences in settlement rates, spatial aggregation, and subsequent density-dependent survival and growth for multiple species through these critical demographic bottlenecks. The findings of such work will provide important information about the role of these early-life history processes in regulating species coexistence in reef corals.

June 19 • 11:35 • Las Jacarandas

Antioxidants enhance coral resilience to thermal stress

Presenter: Maria Alejandra CHACON BUITRAGO

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Anthropogenic stressors are responsible for the collapse of coral reefs. The ocean's rising temperature causes corals to bleach (expel the zooxanthellae living in their tissues) and eventually die at unprecedented scale. In this context, it has become urgent to develop strategies, rooted in our fundamental understanding of the process of bleaching, to enhance the resistance and resilience of corals to warming temperatures. Understanding that coral reefs undergo oxidative stress during and after heatwaves, we tested the use of superfood - *Artemia* enriched with antioxidant vitamin C – in laboratory and field experiments to increase the survival of Red Sea and Caribbean corals exposed to thermal stress. In a 6-week thermal stress laboratory trial, we found that three Red Sea coral species (*Pocillopora damicornis, Turbinaria reniformis*, and *Stylophora pistillata*) fed with superfood were more resistant and more resilient to temperature increases. We then conducted field trials to test how superfood supplements influenced the response of an endangered Caribbean coral species, *Acropora cervicornis*, to a natural thermal stress event caused by the 2023-2024 El Niño event. Physiological and biochemical analysis showed that corals fed superfood in situ before and during the thermal stress event exhibited higher photosynthetic efficiency than those provided with normal food (*Artemia* not enriched in vitamin C). Additionally, corals fed with the superfood showed lower levels of reactive oxygen species during thermal stress and recovery. We also tested how the microbiome of corals fed with superfoods responded to thermal stress compared to those fed with regular food. Corals that were super-fed exhibited minor changes in the taxonomic and functional composition of microbial communities suggesting that vitamin C promotes immune function and therefore reduces susceptibility to microbial infections. Our results showing that antioxidants promote coral resilience support the oxidative

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Visualizing and quantifying *Pocillopora* coral bleaching in Panama's ETP during El Niño with 3D Models and Orthomosaics

Presenter: Ilana S. VARGAS

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Coral bleaching events worldwide continue to increase in frequency, severity, and scale, creating a pressing need to develop effective methods for large-scale monitoring of coral reef conditions and bleaching quantification. The 2023-2024 El Niño brought higher than average sea surface temperatures to the Eastern Tropical Pacific (ETP) of Panama, leading to extensive coral bleaching due to elevated heat stress. The Rohr Reef Resilience (RRR) Project has collected photogrammetry data of *Pocillopora*-dominated reefs in Panama's ETP since 2020. By constructing three-dimensional models and two-dimensional orthomosaics of seven permanent transects in the Gulf of Chiriquí and the Gulf of Panama, we have visualized bleaching occurrences over the last four years. Co-registration and alignment of multiple orthomosaics enables us to track individual colonies over time. Comparing orthomosaics with corresponding samples from the same individual tagged colonies shows the physiological responses of Pocillopora to bleaching. Monthly surveys during the 2023-2024 El Niño year revealed rapid bleaching starting in both gulfs from August 2023, followed by mortality of many bleached colonies by the end of the year. Our findings suggest different responses to bleaching events between Pocillopora types, with one exhibiting far less bleaching and mortality than the other. We also found much more bleaching and mortality in the Gulf of Panama, which experiences seasonal upwelling, compared to the Gulf of Chiriquí, which does not. Our results suggest that acclimatization to strong seasonal temperature fluctuations caused by upwelling does not confer higher resistance to bleaching. Rather, reduced bleaching observed in the Gulf of Chiriqui could be due to adaptation or acclimatization from prior bleaching events, or from lower accumulated heat stress in that region.

June 19 • 13:30 • Gamboa Grand Ballroom

The climate of Barro Colorado Island: 95 years of monitoring

Presenter: Steven PATON

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The suite of climate data collected by the ACP and STRI almost certainly represents one of the longest, uninterrupted climate records for any biological field station located anywhere in the tropics. The length and quality of these data have played an important role in understanding a wide range of ecological processes. These data have appeared in hundreds of peer reviewed publications during the last 50 years. Precipitation data was collected near the laboratory facilities starting in 1925. In 1972, the Environmental Sciences Program (ESP) started collecting a larger suite of climate data (precipitation, relative humidity, air temperature, wind speed and direction, solar radiation). This suite was enough to estimate potential evapotranspiration through models. Later the ESP program tested direct approaches to estimating potential evapotranspiration and settled on Bellini plate atmometers. Starting in 2011, monitoring commenced on the highest part of the Island for the same suite of climate variables, except for potential evapotranspiration.

June 19 • 13:40 • Gamboa Grand Ballroom

Land-atmosphere interactions: The response of a Barro Colorado Island to water stress over multiple temporal scales

Presenter: Matteo DETTO

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Matteo DETTO[1,2], Alfonso ZAMBRANO[2], Helene MULLER-LANDAU[2], and Joseph WRIGHT[2]

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Many tropical regions are experiencing an intensification of drought, with increasing severity and frequency. The ecosystem response to these changes is still highly uncertain. On short time scales (from diurnal to seasonal), tropical forests respond to water stress by physiological controls, such as stomatal regulation and phenological adjustments, to cope with increasing atmospheric water demand and reduced water supply. However, the interactions among biological processes and co-varying environmental factors that determine the ecosystem-level fluxes are still unclear. Furthermore, climate variability at longer time scales, such as that generated by ENSO, produces less predictable effects because it depends on a highly stochastic combination of factors that might vary among forests and even between events in the same forest.

This study will present some emerging response patterns to water stress from an ecosystem exchange perspective using carbon, water, and energy fluxes observed on Barro Colorado Island with a micro-climatic tower equipped with an eddy covariance system. Results show a strong response to atmospheric water demand (e.g., vapor pressure deficit) and soil water availability. The responses range from diurnal stomata control, to seasonal shifts in ecosystem functions such as light-use and water-use efficiencies. Observations also show an increase in productivity during the 2015 El Niño, which is attributed to higher light availability during two unusual dry spells in June and July.

June 19 • 13:50 • Gamboa Grand Ballroom

Drivers of soil carbon emission in warmed tropical soil

Presenter: Andrew Thomas NOTTINGHAM

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Climate warming poses detrimental but poorly understood consequences for tropical forest biodiversity and carbon storage, especially through its impact on soils. To address this uncertainty, the Soil Warming Experiment in Lowland Tropical Rainforest (SWELTR) was initiated on Barro Colorado Island in Panama; one of a few emerging experiments designed to understand the effects of a warmer climate on the tropical land-surface. Here, I describe results following up to three years of experimental whole-profile soil warming, showing high sensitivity of soil organic matter degradation and an unexpectedly large release of carbon dioxide (CO2) to the atmosphere. I consider the biotic and abiotic mechanisms that may be contributing to this CO2 emission and, finally, the research priorities to understand the longer-term and wider-scale implications of warming on tropical forest soils. Better understanding of these feedbacks is vital for developing mitigation strategies to conserve the biodiversity and carbon storage of tropical forests in a warming world.

June 19 • 14:00 • Gamboa Grand Ballroom

Seasonal and experimental drying effects on tropical forest soil respiration: experimental and modeling approaches

Presenter: Lee H. DIETTERICH

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Respiration by soil-dwelling organisms (henceforth soil respiration) is the predominant carbon flux from large pools in tropical forest soils to the atmosphere. Thus, understanding the factors affecting soil respiration is crucial to understanding responses of soil carbon to climate change, as well as the possibility of forest-climate feedbacks. Here we present soil respiration data over an 8-year period centered around Panama Rainforest Changes with Experimental Drying (PARCHED), a throughfall exclusion experiment simulating chronic drying in four Panamanian forests since 2018.

We used baseline soil respiration data to parameterize the Carbon Organisms Rhizosphere and Protection in the Soil Environment (CORPSE) model, which in turn predicted that chronic drying would increase respiration in wet, fertile forests and decrease respiration in dry, infertile forests. Experimental results from PARCHED tended to support these predictions for fertility but not for rainfall. Partitioning measured soil respiration into fine root, fungal, and prokaryotic components has further shown contrasting responses of these organisms to chronic and seasonal drying and soil fertility. These results improve our understanding of how abiotic conditions can affect diverse soil organisms' responses to drying, and may help improve formulations of tropical forest soil respiration in ecosystem models.

June 19 • 14:10 • Gamboa Grand Ballroom

Effects of moisture and density-dependent interactions on tropical tree diversity

Presenter: Edwin LEBRIJA-TREJOS

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Edwin LEBRIJA-TREJOS[1], Andres HERNANDEZ[2], and S. Joseph WRIGHT[2]

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Tropical tree diversity increases with rainfall. Direct physiological effects of moisture availability and indirect effects mediated by biotic interactions are hypothesized to contribute to this pantropical increase in diversity with rainfall. Previous studies have demonstrated direct physiological effects of variation in moisture availability on tree survival and diversity, but the indirect effects of variation in moisture availability on diversity mediated by biotic interactions have not been shown. Here we evaluate the relationships between interannual variation in moisture availability, the strength of density-dependent interactions, and seedling diversity in central Panama. Diversity increased with soil moisture over the first year of life across 20 annual cohorts. These first-year changes in diversity persisted for at least 15 years. Differential survival of moisture-sensitive species did not contribute to the observed changes in diversity. Rather, negative density-dependent interactions among conspecifics were stronger and increased diversity in wetter years. This suggests that moisture availability enhances diversity indirectly through moisture-sensitive, density-dependent conspecific interactions. Pathogens and phytophagous insects mediate interactions among seedlings in tropical forests, and many of these plant enemies are themselves moisture-sensitive. Changes in moisture availability caused by climate change and habitat degradation may alter these interactions and tropical tree diversity.

June 19 • 14:20 • Gamboa Grand Ballroom

Response of tropical tree species to increased temperatures and elevated CO2 concentrations

Presenter: Klaus WINTER

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Klaus WINTER, Jorge ARANDA, Milton GARCIA, Aurelio VIRGO, Martijn SLOT, and Constantin KRÜGER NÚÑEZ

Smithsonian Tropical Research Institute

Biomass accumulation is hardly affected in well-watered, up to 3 m tall *Ficus insipida* grown in naturally illuminated geodesic glass domes at + 5 degree Celsius and 2.5 x ambient [CO2]. Under the same conditions, early growth of well-watered *Ochroma pyramidale* is strongly enhanced. Vegetative growth of the woody *Jatropha curcas* does not change significantly at + 5 degree Celsius, yet production of inflorescences and seeds is strongly reduced or absent at + 5 degree Celsius.

Upper temperature limits are reported for a range of tropical tree species. Thermotolerance was determined by incubating leaf discs at high temperatures in a water bath, by submerging shoots of intact seedlings in hot water, and by subjecting tree seedlings to passive heating in naturally illuminated transparent PVC enclosures or in a glass house. The use of chlorophyll a fluorescence for determining heat tolerance of leaves is critically assessed.

June 19 • 14:30 • Gamboa Grand Ballroom

The integrated resistance of tropical trees to heat and drought stress

Presenter: Louis SANTIAGO

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Louis S. SANTIAGO[1,2], Gabrielle MONEYMAKER[1], Martijn SLOT[2], and Klaus WINTER[2]

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Tree mortality is increasingly associated with elevated frequency, severity, and duration of drought around the world. There is also recent evidence that compound drought-heatwave events are increasing in occurrence and spatial extent, and have the potential to increase the complexity of drought-mortality mechanisms. To better understand how these two environmental stresses interact at the leaf scale, we measured drought tolerance as the water potential at which leaf mesophyll cells lose turgor (leaf turgor loss point; TLP) and leaf thermal tolerance as the temperature at which potential photosystem II efficiency based on chlorophyll a fluorescence starts to decrease (Tcrit) and shows a decrease of 50% (T50) on upper canopy leaves at the San Lorenzo canopy crane in Panama during the 2024 dry season (February – March). We also measured seasonal minimum midday water potential (Psi-min) and midday leaf temperature (Tmax) at the end of March to determine the maximum stress levels reached by each species, as well as leaf structural traits to better understand leaf physical properties related to temperature dissipation.

We found a negative correlation between TLP and T50, indicating that species with the ability to withstand greater water stress without losing turgor pressure in their leaf cells also maintain the integrity of their photosynthetic system at greater temperatures. We discuss our data in the context of exposure to low water potential and high leaf temperatures among species and how the diversity of leaf structure interacts with heating and cooling. Overall, our results show coordination in resistance of tropical trees to multiple environmental stresses, and suggest that these resistances are mediated by similar physiological mechanisms, which offers the potential to simplify characterizing the critical physiological limits of a broad range of species.

June 19 • 14:40 • Gamboa Grand Ballroom

Lianas cool down forest understories but increase light availability

Presenter: Kasper COPPIETERS

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Kasper COPPIETERS[1], Hans VERBEECK[1], Félicien MEUNIER[1], Stefan A. SCHNITZER[2,3], and Marco D. VISSER[4]

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Lianas are an iconic and important feature of tropical forests whose abundance is increasing pantropically. They are undoubtedly linked to negative effects on the carbon storage of forests by reducing individual tree growth and increasing tree mortality and turnover. However, their influence on the energy balance of the forest, and the forest understory microclimate in particular, is poorly understood. To fill this gap, we installed 180 microclimate sensors and 112 light sensors (PAR-sensors and pyranometers) in an ongoing liana removal experiment on Gigante, Panama, which was established in 2011. We used GAMM models to estimate the impact of lianas on the understory temperature and light regime. For half of the plots we were able to account for the impact of forest density on microclimate using simultaneously collected TLS-data. Our findings revealed that the average maximum temperature in liana present plots is 0.25°C lower, with bigger effects in the dry season (up to 0.55 °C lower in the dry season). On top of that, liana present plots are more buffered against extreme temperatures when soil moisture is high. In contrast to the temperatures, there was no difference in the amount of light reaching the forest floor in the dry season. However, on average there was a 90% increase in the amount of light reaching the forest understory in the liana present plots in the wet season. We hypothesize that lianas likely reduce soil understory temperatures in the dry season by increasing the plot level evapotranspiration and increase the amount of solar radiation that penetrates the forest canopy in the wet season by creating more gaps.

June 19 • 14:50 • Gamboa Grand Ballroom

El Niño events, host plant growth, and migratory butterfly abundance in a changing climate

Presenter: Robert B SRYGLEY

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1. Smithsonian Tropical Research Institute. 2. University of California Berkeley. 3. Centro Universitário Una. 4. Universidad del Rosario. 5. University of Arizona

Range and phenological shifts of butterflies are models for effects of environmental change on insect populations. Tropical forests are experiencing a pantropical increase in ambient temperature, and in many regions, the severity and duration of seasonal drought has also increased. Greater leaf productivity by larval host lianas during El Niño in Panama is associated with greater abundance of migrating adult *Phoebis statira* butterflies (Pieridae). This pattern of increased primary productivity resulting in insect outbreaks and migration during El Niño years is called the El Niño Migration Syndrome. To investigate the generality of the El Niño Migration Syndrome, we quantified the abundance of migrating *Marpesia chiron* butterflies (Nymphalidae) over 17 years and production of new hostplant leaves over 9 years in BCNM. We asked whether abundance of migrating insects and productivity of their food plants were associated with El Niño events? We found that the quantity of *M. chiron* migrating across the Panama Canal was directly proportional to the sea surface temperature (SST) anomaly of the Pacific Ocean, which characterizes El Niño. We also found that new leaf production by its larval host trees was directly proportional to the SST anomaly, with greater leaf flushing occurring during the annual butterfly migration during El Niño events. Combining these and our results for the migratory butterfly *Phoebis statira* and its host lianas, we conclude that dry season rainfall and photosynthetically active radiation can serve as primary drivers of larval food production and insect population outbreaks in Neotropical wet forests, with drier years resulting in enhanced plant productivity and herbivore abundance. Insect populations should closely track changes in both frequency and amplitude of the El Niño Southern Oscillation with climate change.

June 19 • 15:00 • Gamboa Grand Ballroom

Using the vertical dimension of forests to test tradeoffs and principles of community ecology

Presenter: Jane LUCAS

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Global change is reshaping communities across our planet by increasing abiotic stress. Taxa tolerant of abiotic stress are expected to benefit from these conditions while less tolerant taxa decline, but we struggle to connect life history tradeoffs to community assembly and responses to global change. This knowledge gap persists because existing studies of community assembly across abiotic gradients are either simplified laboratory experiments or field studies confounded by differences in regional species pools and other factors. Here, we use a novel system – the vertical dimension of forests – to test how abiotic stress shapes community assembly within the same regional species pool and across the same parent material. Abiotic stress increases from the forest floor to the canopy, with a gradient of higher temperatures (3-6°C difference between ground and canopy), drier conditions, and greater microclimate variability developing over only 20-30m of distance. The limited existing evidence suggests that community composition changes continuously across this vertical gradient, and given that these communities assemble from the same regional species pool, these communities must differentiate because of differences in their life history strategies: abiotic tolerances, biotic interactions, and dispersal abilities. We hypothesize that a tradeoff between competitiveness and tolerance may be a crucial functional axis influencing microbial community assembly across abiotic conditions. To test this hypothesis, we sampled communities on standardized wood sticks and in canopy soil using metabarcoding to provide the first replicated assessment of microbial community structure and function along a vertical gradient within a tropical forest. Our research showed near-complete community turnover across the vertical gradient, with indications of a tradeoff from competitiveness-to-tolerance with height. Specifically, antagonistic competitors dominated lower positions, while higher positions exhibited organisms adapted to harsh abiotic conditions. Although limited in scope, this study highlights the potential significance of the competitiveness-tolerance tradeoff in shaping microbial responses to environmental changes. It also emphasizes the utility of exploring the vertical gradient of forests for testing fundamental questions in community ecology.

June 19 • 13:30 • Las Jacarandas

Coacting effects of precipitation and tropical forest fragmentation on the structure and foraging niches of mixed-species foraging aggregations

Presenter: Michael CASTAÑO-DIAZ

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Anthropic activities, in addition to leading to the decline of bird populations, can modify their interactions and behaviors, leading to the disappearance of key elements such as mixed-species foraging aggregations (MSFA). Furthermore, these pressures can interact with environmental effects, potentiating their threat. To understand the influence of precipitation and habitat fragmentation on the structure and foraging niches of understory MSFA, we studied 85 flocks in 19 forest plots along the Panama Canal ranging in size from 9.2 to >11000 hectares and 1500-3100 mm of annual precipitation. We found a total of 1473 individuals and 105 species associated with MSFA. We found an additive effect between precipitation and fragment size on the decrease in the richness of flocks and a higher number of MSFA in the most preserved forest fragments. In small fragments (> 14.1 ha) the flocks practically disappeared. On the other hand, we observed a partition of the foraging niches of the species that make up the flocks, however, we found that the niches located mainly in the understory and on the ground, the substrates exploited in the trunks, and the approach strategies walking or climbing to the substrate, they tend to disappear with the decrease in the size of the fragment. Investigating different aspects of MSFA in current scenarios of intensification of anthropic pressures and rapid environmental change is essential to understand how species mitigate these threats, how these associations can help solve them, and how to design strategies to conserve them.

June 19 • 13:40 • Las Jacarandas

How the environment alters network structure in mixed-species groups of army-ant-following birds

Presenter: Mary DE AQUINO

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Species interactions shape patterns of biodiversity and community structure, and alterations to them can have cascading impacts on populations and communities. However, how environmental variables influence interactions, and the processes modulating impacts across spatial and temporal scales, is not well understood. We examined species interactions in one type of mixed-species animal group – army-ant-following birds – to assess the impacts of environmental variability on network structure. We performed point counts to record species associations at ant swarms and used these to construct species interaction networks. We examined the influence of precipitation, temperature, and different metrics of land cover on network metrics across space, time, and the interactive effects of spatial and temporal variation in environmental variables. Higher precipitation resulted in fewer species interacting at swarms and greater network clustering, which held true across both spatial and temporal (dry versus wet season) scales. The number of species attending swarms increased with decreasing precipitation, while interaction frequency and consistency in interacting species were greatest at moderate precipitation levels. These patterns likely reflect variation in the profitability of attending ant swarms in different environmental conditions and changes in the local bird community across sites. Examining how species interactions are impacted by environmental conditions is critical for understanding the processes modulating species interactions and how interactions will be impacted by anthropogenic change.

June 19 • 13:50 • Las Jacarandas

The impact of climate variation on the inter-specific dynamics of locally adapted *Aedes aegypti* and invasive *Aedes albopictus*

Presenter: Julie I. R. LABAU

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Concerns about the effect of climate change on the rise of arboviruses are growing worldwide, with potential catastrophic consequences for public health. In this context, field-based experiments with *Aedes aegypti* and *Aedes albopictus* mosquitoes—the primary biological carriers of human-pathogenic arboviruses, such as dengue, zika, and yellow fever—remain rare in Mesoamerica. Recent Panama invasion by *Ae. albopictus* in 2002 has forced *Ae. aegypti* to compete for space and resources across the country, resulting in either displacement or coexistence, depending on the local climate. Moreover, STRI identified genomic variation in Panamanian *Ae. aegypti* that exhibits allele partitioning across wet and dry tropical areas, suggesting that climate-adapted populations may have higher fitness in their local environment compared to foreign habitats. Herein, we test the hypothesis that locally adapted *Ae. aegypti* is more resilient to displacement by *Ae. albopictus*, using a reciprocal transplant experiment.
Over the past year, we have gathered eggs of both dry- and wet-adapted *Ae. aegypti* and *Ae. albopictus* using oviposition traps and active surveillance. We have raised larvae from each population to adulthood and established independent mosquito colonies to run reciprocal transplant experiments under lab and field conditions. We monitored mosquitoes under different food regimes and documented their mortality and fecundity rates over time. Consistent with the observed inter-species field dynamics, dry-adapted *Ae. aegypti* cohorts were found to better withstand higher temperatures than *Ae. albopictus* in the lab, whereas *Ae. albopictus* performed better at a lower temperature. Dry- and wet-adapted *Ae. aegypti* and *Ae. albopictus* were then raised and assessed for their relative fitness in the local and foreign field environments. Collectively, we have gathered seven months of climatic data and four months of mosquito phenotypic responses over the wet and dry seasons.

June 19 • 14:00 • Las Jacarandas

The influence of lightning on insect and fungal dynamics within the Barro Colorado Nature Monument

Presenter: Kane A. LAWHORN

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Lightning strikes are a common source of disturbance in tropical forests, and a typical strike generates large quantities of dead wood. Lightning-damaged trees are a consistent resource for tropical saproxylic organisms (i.e., dead wood dependent), but patterns of consumer colonization and succession following lightning strikes are not known. Here, we explored temporal variation in the occurrence of four common consumer taxa—beetles, *Azteca* ants, termites, and fungi—in lightning strike sites and nearby control sites within the Barro Colorado Nature Monument. Beetle abundance was 10 times higher in lightning strike sites than in paired control sites, and beetle assemblages were compositionally distinct between strikes and controls. Beetle assemblages were initially dominated by bark and ambrosia beetles (Curculionidae: Scolytinae), and their associated specialist predators increased in abundance relatively synchronously. At the tree-level, beetle activity and fungal fruiting bodies respectively were 3.8 and 12.2 times more likely to be observed in lightning-killed trees vs. living control trees, whereas the occurrence probabilities of *Azteca* ants and termites were similar between control and struck trees. Tree size also was important; larger dead trees were more likely to support beetles, termites, and fungal fruiting bodies, and larger trees in general were more likely to host *Azteca*. Beetle presence was associated with higher rates of subsequent fungal presence, providing some evidence of beetle-associated priority effects on colonization patterns. These results indicate that lightning strikes play a key role in supporting tropical insect and fungal consumers by providing localized patches of suitable habitat. Any climate-driven changes in lightning frequency in tropical forests will likely affect a broad suite of consumer organisms, potentially altering community and ecosystem-level processes.

June 19 • 14:10 • Las Jacarandas

Lightning disturbance shapes local avifaunal communities in the Barro Colorado Nature Monument

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Canopy gaps caused by tree mortality create significant shifts in localized abiotic conditions in tropical forests. These changes alter local community assemblages in a wide range of taxa including understory plants, arthropods, and birds. Lightning is a significant driver of gap formation in central Panama, and creates structural changes that differ from windfall-induced gaps. We conducted structured avifaunal surveys (point counts and audio recordings) in lightning and windthrow gaps between 2017 and 2023 Woodpeckers commonly used lightning-induced snags for foraging, with foraging signs covering 7.2% (+/- 17.7% SD) of trees killed by lightning compared with 0.4% (+/- 1.5% SD) of windfall-affected trees. Lightning-induced snags were used as nesting sites (0.25 +/- 1.0 nest per site), in contrast with windfall sites, which were never used. These results, in combination with preliminary community-level analyses of audio recordings, suggest that gap structure is a key determinant of local bird species composition.

June 19 • 14:20 • Las Jacarandas

Too hot to handle? The thermal ecology of insect seed predators in tropical rainforests

Presenter: Joshua Aaron JONES

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Joshua A. JONES and Owen T. LEWIS

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Climate change is projected to increase average global temperatures and temperature extremes, which could alter the survival and performance of rainforest plants. Although previous studies have investigated the direct effects of temperature on rainforest seeds and seedlings, we know relatively little about the thermal ecology of their natural enemies. Insect seed predators could be particularly vulnerable to climate change as tropical insects are already thought to be close to their upper thermal limits, and seed predators have a limited capacity to behaviourally thermoregulate when developing within seeds. Overall, we predict warmer conditions will have negative consequences for both seed germination and the survival of insect seed predators developing within seeds, but that the impact on seed predators will be greater. If higher temperatures kill immature seed predators, but not the seeds themselves, this could have important consequences for plant population dynamics, potentially boosting recruitment when seeds are dispersed to warmer microclimates (e.g., forest gaps) or under moderate climate change scenarios. To test our hypotheses, we are conducting a series of experiments on BCI, rearing seeds under different thermal conditions and measuring their germination success and the survival of their seed predators. In this talk, I will present results from a pilot study, where we exposed two woody plant species to heatwave conditions, as well as data documenting how the temperatures experienced by seed predator larvae within seeds differ depending on plant traits and exposure to direct solar radiation.

June 19 • 14:25 • Las Jacarandas

Composition of arthropod rain in a tropical forest

Presenter: Andrew R. SEILER

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Spatially distinct communities are often coupled via subsidies, the asymmetric movement of resources from a donor habitat to a recipient habitat. Arthropod rain, i.e., the fall of arthropods from tree crowns to the forest understory, is a potentially important subsidy link between canopy food webs and detritus-based litter food webs. We used pan and pole traps to sample arthropod rain on Barro Colorado Island, Panama, weekly from June to November, 2023. The mass of arthropod rain averaged 0.925 ± 0.005 mg m-2 d-1 across the sampling period. Ants represented over half of the biomass (0.500 ± 0.002 mg m-2 d-1), followed by Lepidoptera, Araneae, and Blattodea. The role of abiotic (wind, rain) and biotic (army ants, canopy mammals) factors as determinants of temporal variation in arthropod rain density remain to be explored, and ultimately will contribute to our understanding of nutrient dynamics in tropical forest ecosystems.

June 19 • 14:35 • Las Jacarandas

The importance of dorsal landmarks for navigation in dark and cluttered environment by a nocturnal bee

Presenter: Andre SCHEEPERS

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Many insects use visual landmarks to localize their ‘home’ or to return to a food source. But most of our understanding of how insects use landmarks to navigate comes from studies in ‘open’ (eg. deserts) environments, and has focused on the importance of landmarks in the frontal visual field for navigation.

However, in a dark and cluttered jungle at night, the dark canopy forms a high contrast silhouette against the brighter sky that would be visible in an insects’ dorsal visual field. Because high contrast details are more reliable at low light levels, this canopy pattern could be a useful landmark for navigation, particularly for nocturnal species. Here I present results from behavioural experiments showing that the wasp, *Vespula vulgaris*, which is partly forest-dwelling, can use both artificial dorsal visual landmarks and naturalistic ‘canopies’ to locate a food reward. I also present ongoing experiments aimed at revealing how the tropical nocturnal bee, *Megalopta genalis*, is able to navigate using visual landmarks in the jungle under extremely dim-light conditions.

June 19 • 14:45 • Las Jacarandas

Notas de la biología y parásitos de abejas en Panamá

Presenter: Hermógenes FERNANDEZ-MARIN

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Las abejas son polinizadoras de plantas silvestres y plantas agrícolas. Una reducción de la abundancia y diversidad de las abejas va a afectar la capacidad de polinización, y por ende la producción y calidad de los frutos y semillas de plantas que requieren sus servicios. Múltiples factores están conjugándose en la perdida de colmenas de abejas manejas y la diversidad y abundancia de abejas nativas, incluyendo el cambio climático, uso de pesticidas, cambio de uso de tierra, ect. En el neotrópico, la información biológica de la mayoría de las especies de abejas es desconocida o pobremente conocida, y esto dificulta la perspectiva sobre el estatus demográfico de las abejas. Esta falta de información es consistente para las 468 especies de abejas, aproximadamente, que habitan en la República de Panamá. Con la finalidad de construir una plataforma que permita visualizar la estabilidad de las comunidades de abeja en Panamá, he iniciado colectas de datos sobre la biología de las abejas y aspectos culturales asociados con las abejas, en particular de 3 especies de abejas sociales, incluyendo: *Apis mellifera, Melipona panamica,* y *Bombus pullatus*. También, incluyo en esta presentación notas de la biología de una abeja solitaria *Centris* sp. Documentación de la abundancia, distribución, y parásitos de estas abejas es importante para establecer un punto de partida y desarrollar sistemas modelos que permitan enfocar los esfuerzos en entender la estabilidad de las comunidades de abejas en los diversos ecosistemas terrestres de Panamá, y sus respectivos niveles de alteración.

June 19 • 14:55 • Las Jacarandas

Llevando el laboratorio a la práctica: Experiencias con felinos silvestres en Panamá

Presenter: Josue ORTEGA

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En 1999 comenzamos a trabajar en la isla de Barro Colorado (BCI) buscando rastros de los felinos silvestres, principalmente colectando excretas de ocelotes (*Leopardus pardalis*) y pumas (*Puma concolor*). En el 2000 aprendimos la metodología del uso de cámaras trampas (CT) y en el 2001 comenzamos capturas de ocelotes y de su presa principal el ñeque (*Dasyprocta punctata*) para la colocación de collares VHF y posteriormente GPS. De manera simultanea en los años mencionados comenzamos a atender casos de depredación de jaguar (*Panthera onca*) y puma al ganado en la Costa Arriba de Colon y Darién. Entre 2000 al 2004 monitoreamos con aproximadamente 24 CT simultáneamente toda la comunidad de ocelotes residentes e individuos transeúntes por 365 días de cada año. Desde 2001 logramos capturas más de 15 ocelotes para saber el comportamiento y su ecología en general e interacciones depredador-presa. Obtuvimos información sobre los hábitos alimenticios de ocelotes y pumas, además, sabíamos cuántos individuos había en esos años a través de las CT y con video filmadoras automáticas registramos el comportamiento en las letrinas de los ocelotes, y los movimientos espaciales, temporales y comportamiento utilizando principalmente telemetría manual, GPS y el sistema ARTS. Esto fue un entrenamiento en el laboratorio de BCI con todas las técnicas que son utilizadas para entender el comportamiento y el estatus de las poblaciones de estas especies tan elusivas. La experiencia de BCI la hemos llevado a la practica en áreas donde hay conflictos entre vida silvestre y humanos. A través de la Fundación Yaguará Panamá y colaboradores hemos logrado tener mayor conocimiento sobre el estatus del jaguar, otros felinos y sus presas en todo el país utilizando CT y hemos estimado la densidad del jaguar en la zona occidental del país, además de actualizar la información y distribución actual de otras especies en un área de 1,410 km2 con 293 CT entre el Parque Nacional Soberanía hacia el Parque Nacional Darién. Buscando minimizar el conflicto humano y grandes felinos utilizando herramientas como las CT y capturamos jaguares -pumas- para la colocación de collares GPS y así comprender el comportamiento y movimiento en áreas denominadas por humanos y en donde se da la mayor perdida de jaguares y también pérdidas económicas hacia los productores. Hoy día consideramos que la investigación aplicada es importante para resolver o minimizar los conflictos entre humanos y vida silvestre en Panamá y la región.

June 19 • 13:30 • Camino de Cruces

Comunidades bacterianas en la filosfera: Un análisis de la gimnosperma epífita *Zamia pseudoparasitica*

Presenter: Lilisbeth RODRÍGUEZ-CASTRO

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La filosfera representa toda la superficie aérea de las plantas, especialmente las hojas. Es un hábitat extenso y diverso que alberga una amplia variedad de microorganismos, incluyendo bacterias, hongos y virus. Estos microorganismos desempeñan un rol fundamental en la salud y el funcionamiento de las plantas, influyendo en su crecimiento, densidad y función, y, en última instancia, en el ecosistema. Por ejemplo, ciertas bacterias de la filosfera pueden transformar nutrientes como el nitrógeno y el fósforo para que sean utilizados por la planta hospedera. En los bosques panameños, la única gimnosperma epífita estricta del mundo, *Zamia pseudoparasitica*, enfrenta amenazas debido a la pérdida de hábitat y extracción ilegal. Aunque se reconoce la importancia de las interacciones planta-microbio en su adaptación, la diversidad y la influencia de los factores ambientales en la comunidad bacteriana asociada a su filosfera aún no se comprenden completamente.
Este estudio caracterizó la diversidad bacteriana en la filosfera de *Z. pseudoparasitica*, utilizando métodos de metabarcoding. Evaluamos cómo estas comunidades de microorganismos se ven afectadas por factores como la ubicación geográfica, la temporada del año y las condiciones ambientales. Los resultados revelaron una comunidad bacteriana diversa, con 2965 ASV en 115 muestras, representada principalmente por miembros de los phyllum Proteobacteria, Actinobacteriota, Acidobacteriota y sujeta a variaciones estacionales y ambientales, destacando la importancia de comprender estas interacciones para la conservación y comprensión de los ecosistemas.

June 19 • 13:40 • Camino de Cruces

Uncovering the ecology and genomics of predatory amoebae in tropical forest soils

Presenter: Rachel M. SHEPHERD

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Microbial eukaryotes (i.e., protists) are integral members of the soil food web as decomposers, predators, and parasites. Soil amoebae are often ‘top-down’ consumers of bacteria and fungi in belowground systems. By feeding on the primary consumers in the soil food web, predatory amoebae are likely important in controlling the fungal and bacterial energy channels that shape broader ecosystem dynamics, such as the availability of nutrients to plants. Amoebae predation stimulates microbial activity through increased species turnover and the release of nutrients sequestered in their prey. Despite the importance of predatory amoebae in soil, many lineages have only been identified through environmental barcoding, and their contributions to soil processes remain poorly described. The limited genomic representation of soil amoebae hinders our ability to understand their metabolic contributions to ecosystem processes. From our preliminary 18S rRNA gene amplicon data previously collected in Panama, phylogenetically diverse amoebae lineages are abundant and widespread. Here, we aim to characterize the dominant amoebae in Panama tropical forest soils with culturing and genomics approaches. We will also assess soil variables such as pH, soil moisture, and NPK to identify taxa with distinct environmental preferences. These efforts will enable investigations into the functional potential of some of the most highly abundant protist species and their potential impacts on tropical forest ecosystem dynamics.

June 19 • 13:45 • Camino de Cruces

Exploring fungal rhizomorph deterrence of ants in Panama

Presenter: Alice BOSSARD

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Bird species often use fungal rhizomorphs as nesting material in ant-defended swollen-thorn acacias in Panamanian tropical forests. Previous studies indicate that rhizomorphs deter aggressive mutualistic acacia ants *Pseudomyrmex spinicola* from bird nests. However, the use of rhizomorphs in bird nests is widespread in the bird phylogeny, suggesting more general potential adaptive advantages. Our study aims to investigate whether rhizomorph deterrence is a phenomenon specific to acacia ants. Therefore, we exposed two ant species more or less phylogenetically related to *Pseudomyrmex spinicola* to *Marasmius neocrinis-equi* rhizomorphs collected from abandoned bird nests of the yellow-olive flycatcher (*Tolmomyias sulfurescens*). We compare the reactions to the rhizomorphs with the responses towards plant fibers and cotton threads as controls. We recorded the ants' behaviors, comparing the frequency of each behavior (such as biting, grooming, and carrying the material) among the treatments. We also recorded more detailed observations for each behavior, such as time spent grooming and number of pauses while carrying the material to compare between treatments in the two ant species. These results will help us understand the generality of the toxicity of *Marasmius* rhizomorphs towards other ants, which helps illuminate the evolution of the use of this material in bird nests.

June 19 • 13:50 • Camino de Cruces

Fungal alkaloids mediate defense against bruchid beetles in field populations of an arborescent *Ipomoea*

Presenter: Alberto PRADO

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Many Convolvulaceae species harbor heritable fungal endophytes from which alkaloids are translocated to reproductive tissues of the plant host. Evidence for the distribution and ecological role of these fungal alkaloids, however, is lacking or incomplete for many host species and growth forms. Here we report on the quantities of alkaloids present in the leaves and seeds of the arborescent morning glory, *Ipomoea murucoides* (Convolvulaceae). Young leaf samples taken from wild harbored one of two fungal taxa. Seeds had higher concentrations of the indolizidine alkaloid swainsonine than leaves. Additionally, seeds from trees harboring *Ceramothyrium* (Chaetothyriales) fungi exhibited less bruchid damage and had higher concentrations of swainsonine than seeds from trees harboring *Truncatella* (Xylariales) fungi. Five sesquiterpenes were detected in the leaf trichomes of both types of trees. The seed content of the nortropane alkaloids, tropine and tropinone, did not differ significantly among the two fungal symbionts. Overall, our field data support the defensive-symbiosis hypothesis for swainsonine as proposed by Clay (2014) where the fungal partner supplies chemical defenses to the host. It is likely that the host allocates the defensive chemicals from leaves to seeds, protecting them from seed predators such as bruchid beetles.

June 19 • 13:55 • Camino de Cruces

Paleocene origin of a streamlined digestive symbiosis in leaf beetles

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Timing the acquisition of a beneficial microbe relative to the evolutionary history of its host can shed light on the adaptive impact of a partnership. Here, we investigated the onset and molecular evolution of an obligate symbiosis between Cassidinae leaf beetles and Candidatus *Stammera capleta*, a γ-proteobacterium. Residing extracellularly within foregut symbiotic organs, *Stammera* upgrades the digestive physiology of its host by supplementing plant cell wall-degrading enzymes. We observe that *Stammera* is a shared symbiont across tortoise and hispine beetles that collectively comprise the Cassidinae subfamily, despite differences in their folivorous habits. In contrast to its transcriptional profile during vertical transmission, *Stammera* elevates the expression of genes encoding digestive enzymes while in the foregut symbiotic organs, matching the nutritional requirements of its host. Despite the widespread distribution of *Stammera* across Cassidinae beetles, symbiont acquisition during the Paleocene (62 mya) did not coincide with the origin of the subfamily. Early diverging lineages lack the symbiont and the specialized organs that house it. Reconstructing the ancestral state of host-beneficial factors revealed that Stammera encoded three digestive enzymes at the onset of symbiosis, including polygalacturonase—a pectinase that is universally shared. Although non-symbiotic cassidines encode polygalacturonase endogenously, their repertoire of plant cell wall-degrading enzymes is more limited compared with symbiotic beetles supplemented with digestive enzymes from *Stammera*. Highlighting the potential impact of a symbiotic condition and an upgraded metabolic potential, *Stammera*-harboring beetles exploit a greater variety of plants and are more speciose compared with non-symbiotic members of the Cassidinae.

June 19 • 14:05 • Camino de Cruces

The evolution of insect pheromone biosynthesis: A case study in *Heliconius* butterflies

Presenter: Kathy DARRAGH

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Both plants and insects produce a vast diversity of chemical compounds. These compounds are used for a variety of different functions including attracting mates, attracting pollinators, and defense against predators and herbivores. Interestingly, insects and plants have independently evolved the ability to produce the same compounds. In most systems, especially in insects, the enzymes and biosynthetic pathways underlying compound production is unknown. In fact, in some cases it was thought that insects could not biosynthesize certain compounds and instead were reliant on consuming plants to sequester the compounds. I will discuss, using an example from *Heliconius* butterflies, how I have combined chemical ecology, evolutionary biology, and molecular studies to better understand the evolution of insect pheromone synthesis. I will describe the discovery of a novel terpene synthase in *Heliconius*, the first known in Lepidoptera. I will also discuss future research directions I propose to take including work here at STRI.

June 19 • 14:15 • Camino de Cruces

Interacting effects of moisture and biotic interactions on seedling recruitment in tropical forests

Presenter: Hilario ESPINOSA

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Introduction
Tropical forest diversity is maintained through mechanisms such as conspecific negative density dependence (CNDD). It is important to understand how moisture and its interaction with other factors such as the closeness to the mother tree affects plant performance in tropical rainforests.

Objective
Analyze the effect of different levels of rainfall manipulation on seedling survival under conspecific and heterospecific trees.

Methods
Ten trees of three species (*Drypetes standleyi, Pouteria reticulata*, and *Heisteria concinna*) were selected as focal species (conspecific) and each conspecific tree had a paired heterospecific tree chosen randomly. Under each tree, we set up three cages subjected to a different moisture treatment: 25% addition of natural precipitation, control, and 25% subtraction of natural precipitation. We planted 20 conspecific seeds under each cage and monitored for 10-12 months. We performed statistical analysis using a Generalized Linear Mixed Model with a logit link.

Results
Seedlings had a higher chance of survival below the canopy of large heterospecific than conspecific trees. This was observed for all tree species analyzed. Additionally, seedlings subjected to reduced precipitation tended to survive better than those subjected to additional or natural precipitation, with differences being significant towards the end of the experiment for one species.

Implications
A previous long-term seedling dynamics study showed that changes in moisture levels can significantly impact CNDD with lasting effects on seedling diversity as originally proposed by Janzen. Though in a limited number of species, we show for the first time in a field experiment that alterations to moisture availability can affect interactions with conspecific and heterospecific trees.

June 19 • 14:25 • Camino de Cruces

The role of frequency-dependent selection in controlling the expansion of clonal aggregations in the tropical forest understory: Insights from a decade-long experiment.

Presenter: Eloisa LASSO

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Sexual reproduction, despite its associated costs and risks, is prevalent among many organisms, presumably to generate and maintain genetic diversity. Paradoxically, several clonal species also exhibit high genetic diversity. One theory for the maintenance of this genetic diversity is frequency-dependent selection, which favors rare genotypes over common ones, limiting the extent and dominance of a single clone, thereby preserving genetic diversity. Empirical evidence for this theory under natural conditions is sparse. Twelve years ago, we established in the Barro Colorado Monument fourteen genetically diverse plots where all plants had a unique genotype (rare genotypes) and paired with them clonal plots where all plants had the same genotype (common genotypes). Clones were created from cuttings from *Piper cordulatum*, a clonally reproducing understory plant. We tested whether common genotypes have a disadvantage and frequency-dependent selection is in action. Over the experiment's first ten years, herbivory, pathogen attacks, and plant size remained similar across both genotype categories. Intriguingly, clones exhibited superior survival during the initial five years. By the end of the decade, survival rates equalize for rare and common genotypes. By year twelve, data from projections based on this decade-long trend coincided with observed survival data collected in the twelfth year, with common genotypes showing slightly higher mortality in the long run, consistent with the hypothesis of negative frequency-dependent selection. Moreover, plants in clonal plots had reduced fitness in terms of their fruit production. Our findings suggest that the impact of negative frequency-dependent selection is not immediate but could eventually restrict the survival and reproduction of *Piper* clones, curbing the dominance of any single genotype and potentially enhancing population-wide genetic diversity.

June 19 • 14:35 • Camino de Cruces

Realizing the potential of native microbes in the agricultural sector: From basic studies of fungi interactions to sustainable management of diseases in the tropical tree crops coffee and cacao

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It is recognized that foliar endophytic fungi can confer hosts trees with increased tolerance to adverse abiotic and biotic factors. Nonetheless, evidence for the role of endophytic fungi on host trees tolerance to biotic stresses was scanty twenty years ago. Here we present an overview of studies conducted in Panama, that started with pioneering work in Barro Colorado Island, on the diversity and role in plant defenses of endophytic fungi associated with the tropical trees *Theobroma cacao* and *Coffea arabica*. Results will be presented on the effects of host genetics on endophyte community diversity and on the effects of endophytes on host genetics. Insights into the relevance of incorporating the generated knowledge to plant breeding programs and long-term management of diseases will be provided. We found high diversity of fungi associated with *C. arabica* in Panama, with fungal community composition influenced by plant organ, source locality, management (organic vs conventional farming), and time of the year. Formulations based on selected endophytes did biological control of pathogens of coffee and cacao under farm conditions. Overall, our results support the use of endophytes as crop protectant for managing diseases in these tropical tree crops and a future less dependent on the use of toxic conventional pesticides.

June 19 • 14:45 • Camino de Cruces

Cultivating resilience in the tropics: Exploring *Theobroma cacao* genotype-mycobiome interactions for disease management

Presenter: Hilda E. CASTILLO

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Theobroma cacao is an essential tropical tree crop and its production is seriously affected by diseases such as Frosty Pod Rot (FPR), caused by the fungus *Moniliophthora roreri*. Our research aims to understand the relationship between cacao genetics and the microbial communities within their pod, focusing on building disease resistance on Panamanian cacao farms. Through a comprehensive analysis involving metabarcoding of endophytic fungi communities across four cacao genotypes with differences in agronomic traits, we identify a rich fungal diversity within cacao pods. Our findings indicate changes in alpha diversity of the pod mycobiome according to plant genotype.

We conducted a field trial to evaluate two bioactive cacao pod endophytic fungi, *Waltergamsia zeylanica* TCF417 and *Clonostachys rosea* TCF400 on their capacity to biologically control FDR in two *T. cacao* genotypes (CATIE R1? And EET?): We found that *C. rosea* TCF417 was able of reduce *M. roreri* sporulation.

Additionally, molecular characterization of Panamanian cacao germplasm collected during the course of this project using Single Nucleotide Polymorphism (SNP) markers revealed substantial genetic diversity, including prevalent Criollo and Amelonado varieties, alongside other genetic backgrounds such as Nacional and Marañon. This diversity is essential for the adaptability and resistance of crops to disease.

Our findings highlight the complex interplay between the genetic characteristics of cacao plants and their associated mycobiomes. By harnessing this relationship, sustainable farming practices can be advanced significantly. We recommend that cacao breeding programs integrate this understanding of cacao genetics and microbial diversity to combat disease more effectively and to promote the long-term sustainability of cacao agriculture amidst evolving environmental pressures.

June 19 • 14:55 • Camino de Cruces

Biological control as a conservation science: From promise to action

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Historically, the disciplines of conservation biology and biological control have acted in isolation – independently pursuing environmentally-sound measures in either agricultural habitats or off-farm settings. This 'silo approach' however has been to the disadvantage of either discipline. In this presentation, I draw on curated, open-access ecological interaction data to visualize to what extent natural enemies of a key crop pest – the fall armyworm *Spodoptera frugiperda* (FAW; Lepidoptera: Noctuidae) – interact with non-cultivated plants and animals in natural habitats. Specifically, tri-partite networks link 80 FAW natural enemies (invertebrate or microbial) to 512 lepidopteran hosts and no less than 1194 plants. These comprise threatened herbaceous or woody plants and conservation flagships such as saturniid moths. Hence, the on-farm conservation or augmentation of naturally-occurring natural enemies (e.g., for biological control purposes) can secure the trophic structure and ecological regulation of native butterflies and moths, regenerate natural vegetation, and advance restoration outcomes. Our work shows how closer cooperation between conservation biology and biological control disciplines can be mutually beneficial. In the pursuit of a more biodiverse planet, the conservation-agriculture divide needs urgent mending, and network ecology points the way.

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Posters

P1

June 19 • Poster • Gamboa Grand Ballroom

Riqueza, abundancia y diversidad de murciélagos en los alrededores del hotel Summit Rainforest Resort & Golf Panamá, provincia de Panamá

Presenter: Melissa LÓPEZ GONZÁLEZ

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Los murciélagos juegan un papel esencial en el equilibrio de los bosques y pueden ser utilizados como indicadores de la calidad ambiental, por lo que este grupo faunístico es de gran importancia debido a los servicios ecosistémicos que brindan. En este trabajo se documentó información sobre las especies de murciélagos observadas en los alrededores del Hotel Summit Rainforest Resort & Golf Panamá, ubicado entre el Parque Nacional Camino de Cruces y la vía Omar Torrijos Herrera, corregimiento de Ancón, Provincia de Panamá. Las capturas se realizaron durante los meses de enero, febrero, agosto y septiembre del año 2020. El objetivo de este estudio consistió en obtener registros de la población de quirópteros del área, para conocer la riqueza de especies, sus estados reproductivos y los gremios tróficos que ocupan. Se logró el registro de 342 individuos, pertenecientes a 21 especies y dos familias, destacando la familia Phyllostomidae con el 99% de las especies registradas. La riqueza de especies obtenida representa en 18% del total de murciélagos conocidos para Panamá; de las cuales *Artibeus jamaicensis, Uroderma bilobatum y Carollia perspicillata*, demostraron ser las especies las más abundantes, sin embargo, se lograron ver variaciones en cuanto a la proporción sexual, estados reproductivo y edad de los murciélagos registrados en relación con la temporada seca y lluviosa comprendidas en este estudio.

P2

June 19 • Poster • Gamboa Grand Ballroom

Social information use in foraging *Artibeus jamaicensis*

Presenter: Brandi CHRISTIANO

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Social information can influence various aspects of an animal's ecology, including life-long behaviors and decisions. The costs and benefits of relying on social information must be carefully considered. When obtaining social information becomes prohibitively expensive, animals may resort to independent information gathering. Jamaican fruit-eating bats (*Artibeus jamaicensis*), with their long lifespans (40+ years) and exposure to variability and unpredictability, are excellent candidates for studying social learning. In this study, we investigated whether wild-caught A. jamaicensis prefer social information over individual information and whether group size influences their foraging decisions. We tested three hypotheses: H1) Bats use familiar information for foraging decisions. H2) Bats rely equally on social and individual information. H3) Group size affects foraging choices. Our findings partially support the first hypothesis, revealing a strong trend toward bats choosing familiar foods. Surprisingly, we found no difference in the number of bats choosing socially learned versus individually learned food. We partially support our third hypothesis and find a strong trend for bats to choose food that the minority of group members smelled like. We discuss potential reasons for this species' limited reliance on social information, despite evidence from other fruit-eating bats. Sex differences may play a role in shaping their foraging strategies.

P3

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Patrones territoriales en el murciélago de ventosas, *Thyroptera tricolor*

Presenter: Silvia CHAVES-RAMÍREZ y Mariela SÁNCHEZ-CHAVERRÍA

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La disponibilidad de recursos puede influenciar los patrones de uso del espacio y comportamiento de las especies. Para especies especialistas en un recurso, la distribución y abundancia de este puede llevar a la competencia y, por lo tanto, a su defensa. *Thyroptera tricolor* es una especie de murciélago social que es especialista en la utilización de un refugio efímero; además, presenta modificaciones en sus extremidades que le impiden usar otro tipo de refugio. Por lo tanto, los refugios representan un recurso crítico y potencialmente defendible para esta especie. En esta investigación el objetivo principal fue evaluar la posible territorialidad de grupos sociales de *T. tricolor*. Para ello se estudió el solapamiento de los ámbitos de descanso, los cuales se determinaron mediante el método de densidad de Kernel. Además, identificamos comportamientos agonísticos durante un contexto de defensa del refugio y también pusimos a prueba las hipótesis del “querido enemigo” y “vecino desagradable”. Para lo anterior realizamos experimentos estudiando las respuestas comportamentales de un grupo focal cuando interactuaba con diferentes intrusos durante la ocupación de un refugio. Nuestros resultados demuestran que los grupos de *T. tricolor* mantienen ámbitos exclusivos de descanso en disponibilidad intermedia de refugios. Aunado, encontramos que *T. tricolor* utiliza vocalizaciones agresivas durante internaciones intergrupales. Los patrones espaciales y comportamentales encontrados en este estudio sugieren que *T. tricolor* es una especie territorial.

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Prey-capture techniques of an ant-eating jumping spider, *Corythalia pulchra* (Araneae: Salticidae), from Panama

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Versatile predators adjust hunting strategies to their prey. Ant-eating, or myrmecophagous, jumping spiders (Salticidae) use prey-specific prey-capture behaviors. With acute vision, these salticids can discriminate various insect prey. *Corythalia pulchra*, a common salticid in the Panama Canal Zone, was observed preying on the ant *Pseudomyrmex spinicola* (Pseudomyrmecinae), an obligate mutualist of the swollen-thorn acacia species *Vachellia collinsii*, and carton nest-building arboreal ants from the genus *Azteca* (Dolichoderinae). This study seeks to determine whether *C. pulchra* adjusts predatory behavior for ants with different defenses. Because *Azteca* ants lack the sting present in P. spinicola, *C. pulchra* may benefit from utilizing different prey-capture behaviors for each. *C. pulchra* were collected in acacia patches and near trees with *Azteca* nests (Parque Natural Metropolitano, Panama) for laboratory experiments. Individuals were offered live P. spinicola and *Azteca* sp. in random order on two consecutive days. From video recordings, I measured prey capture success, the distance and direction spiders attacked from, the sequence and timing of predation stages, and details about post-capture handling. Additional predatory sequences were recorded using a high-speed camera to observe capture mechanics in finer detail. Still ongoing, this project will help in understanding prey-capture techniques and prey preferences of *C. pulchra* and the importance of behavioral specialization toward particular ant prey in myrmecophagous salticids.

P5

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COVID-19 induced lockdown: assessment of ground-dwelling wildlife responses to reduced human presence on Barro Colorado Island

Presenter: Claudio Manuel MONTEZA-MORENO

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On a world dominated by humans, interactions between humans and wildlife is unavoidable. The consequences resulting out of this co-existence translate into a challenge for wildlife, with cascading effects bouncing back to humans. Thus, to reinforce conservation and sustainable efforts, gathering information about wildlife adaptations to areas with human presence is important. Previous studies suggest that humans impact wildlife both negative and positively. Though depicting the mechanisms inducing human impacts on wildlife is limited due to sampling design constraints, as studies are limited to use a gradient of human presence and/or general footprint. In 2020, however, during COVID-19, humans were induced to reduce worldwide mobility to a great degree. This anthropause allowed for a quasi-natural experiment, especially in protected areas where the access to humans was restricted, such as Barro Colorado Island (BCI), in Panama. Here, we assessed the impact of the mere human-presence on ground-dwelling mammals at a fine-scale, by comparing four months of trail-based camera trap data from 2019 where humans frequented BCI trails vs four months from 2020, with reduced human presence. To assess whether or not the temporal and spatial habitat use of wildlife differ between both years, we used activity patterns and Generalized Linear Mixed Models TMB, respectively. We also used survival analysis to evaluate the interaction (waiting-times) of the main predator in BCI, the Ocelot (*Leopardus pardalis*), and its main prey, the agouti (*Dasyprocta punctata*). Our preliminary results suggest that while human presence on BCI dropped down markedly, in general, species spatial use was fairly similar between both years. Though we observed slightly higher monthly rate on Collared-peccary (*Pecari tajacu*), Great tinamou (*Tinamus major*), and Red-tailed squirrel (*Sciurus granatensis*). Whereas, most notorious decrease in monthly rate was for ocelot. Temporal shifts were mainly observed in White-nosed coati (*Nasua narica*), Collared peccary and Red-tailed squirrel, with high activity on times of the day where humans are most presence in the forest. Our results for waiting time suggest that agouti and ocelot´s active avoidance and tracking, respectively, does not differ markedly between years. However, agouti active avoidance of ocelot is slightly lower in the presence of humans, and ocelots active tracking slightly less pronounce in the absence of humans. Our findings suggest that the mere presence of humans, generally, does not impact species temporal and spatial patterns of habitat use, with some species-specific responses; and that our results do not support the human-shield hypothesis.

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La contribución de las aves a la dispersión de semillas en áreas degradadas

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La restauración de áreas degradadas genera una variedad de beneficios, como captura de carbono, creación de corredores naturales para la biodiversidad, y mejora de la calidad del agua. Sin embargo, en las áreas tropicales la mayoría de los árboles grandes necesitan la ayuda de los animales para distribuir sus semillas. Este proyecto evalúa la contribución de las aves a la dispersión de semillas en áreas degradadas usando DNA metabarcoding. Se colocaron 50 trampas de semillas con perchas a lo largo de transeptos que se extienden desde el borde del bosque hacia las áreas abiertas en tres paisajes con diferentes niveles de fragmentación (20,40 y 60 % cobertura vegetal) cerca de Barro Colorado- Panamá. Se colectaron semillas y muestras de heces en las trampas una vez por semana y se congelaron hasta su procesamiento en el laboratorio. Para identificar la especie de aves dispersoras y las especies de árboles dispersadas a diferentes distancias del borde del bosque, se extrajo el ADN con el Quick-DNA Fecal/Soil Microbe Kit (Zymo) y se amplificó el locus CO1 y ITS2, respectivamente, usando la secuenciación masiva de Illumina. Los resultados serán utilizados para validar un modelo que predice la contribución de distintas aves a la dispersión de semillas de distintas especies de árboles a lo largo que la distancias al borde del bosque aumenta en paisajes con diferentes niveles de fragmentación.

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¿Varían las recompensas para las hormigas según la defensa que proveen a la planta hospedera?

Presenter: Maikol GUEVARA PEREZ

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Las plantas conocidas como “mirmecófitas” proporcionan alimento y refugio a las hormigas a cambio de que estas actúen como sus guardaespaldas y las defiendan contra herbívoros, patógenos e inclusive otras plantas. Para garantizar la rentabilidad de la interacción, las mirmecófitas deben regular su inversión en recompensas para las hormigas en función de las condiciones locales y la presión de los herbívoros. Investigamos cómo la inversión de las mirmecófitas en recompensas múltiples se relaciona con la defensa y la ocupación de las hormigas a lo largo del tiempo, usando las recompensas producidas por las acacias (*Vachellia collinsii*) bajo diferentes condiciones de ocupación (i.e., la especie de hormiga presente en los árboles de acacia monitoreados). Comparamos las recompensas alimenticias (número de nectarios extraflorales y pínnulas como indicador de cuerpos alimenticios) y las recompensas de alojamiento (dimensiones de los domacios) de *V. collinsii* en dos condiciones: (1) árboles defendidos por *Pseudomyrmex spinicola* (la especie mutualista obligada) vs. árboles sin hormigas; y (2) árboles ocupados por hormigas que proveen un gradiente de defensa (alta: *P. spinicola*, media: *P. simulans*, baja: *Crematogaster crinosa*). Para distinguir plasticidad de variación entre individuos, medimos las recompensas en dos puntos en el tiempo. Las recompensas de comida variaron dependiendo de la ocupación y especies de hormigas. Por el contrario, los domacios variaron únicamente con la condición (ocupación o especie residente) y menos en el tiempo. Nuestros resultados revelan una plasticidad a corto plazo en las recompensas para las hormigas de *V. collinsii* y demuestran que las mirmecófitas con recompensas constitutivas pueden ajustar su inversión dependiendo de la presencia e identidad de las hormigas presentes.

P8

June 19 • Poster • Gamboa Grand Ballroom

Plant-pollinator interaction network between diurnal Lepidoptera and flowering plants in the Atlantic Forest

Presenter: Alessandra MIKICH

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Mutualistic interactions are a determining factor in biodiversity maintenance. Despite this, large community ecological studies on the interactions between flowering plants and flower-visiting Lepidoptera are still scarce, especially in the Neotropics. Given that, we aimed to determine the identity and richness of diurnal Lepidoptera as well as their interactions with flowering plants and analyze the structure of the interaction network. Between June 2019 and May 2022, we observed 352 plant species in two Atlantic Forest remnants in Southern Brazil (Paraná State). In total, 3,283 butterflies and moths were actively collected with entomological nets while visiting the flowers of 144 plant species. These specimens represent 330 butterfly and 74 diurnal moth species, which belong to seven and twelve families, respectively. As expected, the highest number of species and abundance belonged to Hesperiidae, with 1,906 individuals distributed in 202 species. We found that Bidens alba, *Vernonanthura beyirichii* (Asteraceae), and *Stachytarpheta cayennesis* (Verbenaceae) are important feeding sources for over half the flower-visitor community. Accordingly, Asteraceae is the most visited family by flower-visiting Lepidoptera, with 1,535 interactions, followed by Verbenaceae (515) and Fabaceae (339). The Lepidoptera-plant mutualistic network showed a significantly nested and non-modular structure. Moreover, it exhibited low connectance and degree values, as well as intermediate and significant robustness, which is a common pattern in pollination networks. In conclusion, this study provides insightful information into the community structure and interspecific interactions between Lepidoptera and flowering plants, which can be useful for conservation actions in the Atlantic Forest biome.

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Swollen-thorn acacias invested more in their defending ants during El Niño 2023

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Resource allocation in plants varies in response to the environment. Extreme climate events such as droughts can disrupt normal patterns of reproduction and growth. Obligate mutualisms may be particularly sensitive to such events, as shifts in the resource allocation of one species may come at the expense of investments in its partner. Swollen-thorn acacias (*Vachellia collinsii*) are myrmecophytes in a defense obligate mutualism with several *Pseudomyrmex* species. The ants defend the plant from herbivory and competition with encroaching vegetation. In return, the acacias provide the ants with hollow spines to nest in as well as food, consisting of extrafloral nectar and amino acid-rich Beltian bodies. The production of these rewards is plastic both temporally and under different occupancy conditions. In 2023, we revisited swollen-thorn acacias which were measured for these traits in 2019 to assess whether an El Niño-associated drought impacted the investment of these plants in their defending ants. We found that swollen-thorn acacias produced larger spines, more nectaries, and more Beltian bodies during El Niño 2023. The rate of herbivory was higher in 2023 than in 2019, which may explain why acacias' investments in indirect defense by ants increased. We are uncertain about whether the increase in herbivory during El Niño 2023 was due to the heightened activity of herbivores, or by the inability of the ants to patrol the plant effectively. By demonstrating how this system behaved during an El Niño event, this study provides insight into the stability of this obligate mutualism under stressful conditions.

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Trial using live vaccination in chytridiomycosis-susceptible *Atelopus glyphus* leads to worse disease outcomes than controls

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Understanding the efficacy of vaccination on host survival during population-level epizootics remains an important frontier of animal research. Amphibian disease systems in particular have been an important nexus for understanding this aspect of the immunity interface and its role in both conservation and eco-evolutionary dynamics. *Batrachochytrium dendrobatidis* (Bd), the causal pathogenic agent of amphibian chytridiomycosis, has been implicated in large-scale epizootic events resulting in amphibian declines and extinction. Susceptibility to extinction, however, appears to be mediated by complex interactions with the host immune response. We therefore hypothesized that live vaccination, using Bd exposures followed by clearance with the antifungal itraconazole, and subsequent Bd infection of *Atelopus glyphus* would reduce Bd infection loads. This would also increase the skin mucoscal inhibitory function and increase survival in captive populations, thereby ameliorating disease outcomes. Our mucosome function assays indicated limited alteration of function between treatment groups. Differences in mortality were observed with the vaccination treatment group experiencing faster mortality, counter to our expectations. Additionally, there was a distinct positive correlation between Bd load at first exposure and second exposure. If an effective acquired immune response was manifest, we would have expected a higher vaccination dose would lead to a lower subsequent infection. This was not observed. Our results demonstrate that in highly Bd-susceptible *Atelopus* frogs there is currently limited support for the efficacy of vaccination in mediating chytridiomycosis.

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The ecological and genetic basis of colorful signal evolution in the slender anole (*Anolis apletophallus*)

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Environmental change is rapidly altering many regions of the globe, which can impact the fitness and distributions of animal populations. One poorly studied impact of climate change is how shifts in habitat structure will alter transmission of animal signals. These traits are important for communication with con- and heterospecifics. Lizards in the genus Anolis have long been a model system for evolutionary studies, but little is known about the evolutionary dynamics of the dewlap, a well-known visual signal that is most prominent in the males of most anole species. The Panamanian slender anole (*Anolis apletophallus*) is an ideal system for studying signal evolution as their dewlap is polymorphic in color pattern; males can be solid morph (completely orange dewlap) or bicolor morph (white dewlap with an orange basal spot). We have been studying the slender anole dewlap for several years, combining genomic analyses and detailed spatial data collected across an understory light gradient on the mainland with a large-scale transplant experiment to understand the ecological causes and genetic basis of dewlap evolution. We have found no evidence of genetic differentiation between morphs at our mainland site, and they are similar in morphology, physiology, and ecology. However, solid morph frequency is higher in areas with greater canopy openness, in line with the sensory drive hypothesis. Through breeding experiments and pooled sequencing, we have discovered that dewlap pattern is controlled by a single locus with the solid allele dominant to the bicolor allele, and that the causal locus is probably the transcription factor single-minded 1 (SIM1). Island transplants have revealed that shifts in understory light levels can lead to rapid evolution of dewlap color that recapitulate the patterns we observe on the mainland. Our research is demonstrating the ways in which understory light levels can drive evolutionary change in dewlap color and maintain polymorphism in nature. Future work will continue to clarify how the interaction between the environment and the genome shapes the evolution of this signal.

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Ecological correlates of a female-limited dorsal color pattern polymorphism in the slender anole (*Anolis apletophallus*)

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Coloration and patterning can play a critical role in organismal fitness, especially when color patterns are present in discrete morphs (i.e., polymorphism). In many *Anolis* species, dorsal pattern polymorphisms are often sex-limited, with females typically being more polymorphic than males. However, the reasons for female-limited pattern polymorphisms are still unclear, with several studies suggesting that microhabitat use or differential predation rates may play roles in this phenomenon. The slender anole (*Anolis apletophallus*) is distributed across an ecological gradient in central Panama and exhibits a female-limited polymorphism in dorsal patterning making it a tractable system to link ecological variation and natural selection to molecular evolution. In this study, we explored how variation in female color patterning is maintained in populations of the slender anole. Leveraging morphological, physiological, behavioral, and environmental data collected over seven years, we 1) characterized phenotypic variation in female slender anoles, 2) determined if female color pattern morph frequencies are associated with either broader geographic or finer-scale microhabitat variation, and 3) identified the underlying genetic architecture of female color pattern polymorphism. This study contributes to our mechanistic understanding of the processes generating and maintaining female-limited pattern polymorphisms in the wild.

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Knockdown of gene regulatory network components in Heliconius butterflies using dsiRNA

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Heliconius butterflies are a group whose diverse wing patterns are driven by complex mimicry rings. The diversity in color patterns are generated by a regulatory network of genes, few of which have a known identity and function. By injecting pupal wings with dsiRNA probes for Fz2, SS, and Optix, we aim to shed more light on the role of each gene in butterfly wing pattern development.

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Unveiling reference genes for gene expression analyses in *Heliconius erato lativitta*

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The Neotropical butterfly *Heliconius erato lativitta* has been used as a model organism for the study of evolutionary adaptations, speciation, and genetic bases. This species is mainly recognized for its wing color pattern mimicry. However, the molecular mechanisms involved in adaptation to temperature changes remain unidentified. In this sense, quantitative real-time PCR (qPCR) has resulted one of the most useful tools to elucidate the molecular mechanism through the quantification of the mRNA of genes involved in the adaptation of this species. Nevertheless, the accuracy and reliability of qPCR data depends on the proper selection of reference genes, whose expression profiles must remain stable across different experimental conditions. Therefore, in this work six genes (ACT1, ACT2, ANX, AK, eEf1α, and eEf1α2) from *H. e. lativitta* were used as candidate reference genes and their expression level was assessed at different temperatures in three type of tissues both for males and females. The stability of reference genes was evaluated using three algorithms geNorm, NormFinder and RefFinder. The results obtained with these algorithms indicate that AK and ACT2 are stables under temperature stress. However, at the tissue level, only ACT1 and AK were the most stable genes, while at the sex level, only ACT1 and ACT2 exhibited a high stability. Hence, this study provides a standardized set of reference genes for future gene expression analysis using qPCR in *H. e. lativitta*

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Development of taxon-specific molecular probes to track the density and distribution of phytopathogens in tropical forests

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Tropical forests are among the most diverse plant communities in the world, however, the mechanisms underlying this diversity remain poorly defined. The Janzen-Connell hypothesis (JCH) predicts that host-specific natural enemies, such as herbivores and pathogens, maintain plant diversity by increasing the mortality of densely populated conspecific seedlings and seedlings growing near conspecific adults (conspecific negative density and distance dependence; CNDD). Support for the JCH includes evidence that pathogens significantly reduce the performance of *Virola nobilis* seedlings growing near their mother trees compared to those distributed farther away. *Calonectria* fungi cause significant *V. nobilis* seedling mortality on Barro Colorado Island (BCI), however, whether their densities and distributions respond to those of *V. nobilis*, as postulated by the JCH, remains unresolved. Typical methods for the molecular characterization of fungi, such as metabarcoding of the internal transcribed spacer region, are insufficient for analyzing *Calonectria* spp. spatial and host distributions since they lack quantitative abilities and species-level resolution for the genus. We have therefore designed species-specific molecular probes targeting regions of genetic variation in *Calonectria* isolates from BCI. To optimize these probes for *Calonectria* spp. quantification in field samples, we will determine DNA extraction efficiency from soils with defined spore amounts and use quantitative polymerase chain reactions (qPCRs) to correlate DNA quantities with sample spore counts. We can then use these molecular probes to investigate how *Calonectria* spp. densities respond to host density and proximity. Such work will allow us to address undertested assumptions of the JCH with speed and efficacy, and elucidate the mechanisms underlying the incredible plant diversity of tropical forests.

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How are phytopathogenic fungi distributed across tree species? Implications for the rol of phytopathogens in the maintenance of forest diversity

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Host-specialized phytopathogens are credited with the maintenance of tropical forest diversity. However, the phytopathogens and their interactions with plants are understudied. The hyperdiversity of tropical forests and the relative rarity of individual tree species suggest there is evolutionary selection for pathogens with broad host ranges. Yet, host-generalist phytopathogens can operate as effective specialists by exhibiting host preference in the form of host affinity. We are examining the foliar pathogen communities of three tree species in the seasonally dry tropical forest of Parque Natural Metropolitano (*Anacardium excelsum, Castilla elastica,* and *Luehea seemannii*). We focus on host species with known relative abundances in a defined geographic area because host affinity can be detected when host use frequency is decoupled from the relative abundance of host species. We hypothesized that common fungal species are associated with all three tree species but that their relative abundances vary across host species. Additionally, we expected the pathogenic genera to be those observed in previous studies of seedling pathogens in tropical forests. To test our hypothesis, we isolated putative pathogens from diseased leaves and, once in pure culture, identified them to genus and assigned them to operational taxonomic units (OTUs) with the fungal barcode ITS. Additionally, we experimentally assessed the pathogenicity of 170 isolates with shadehouse-based inoculation experiments, following Koch's postulates. Of the 15 OTUs observed three or more times, half were found in all three tree species and only one OTU, Nigrospora sp. 1, was isolated (three times) from a single tree species, C. elastica. The most frequently isolated OTU of *Colletotrichum* (sp.1) occurs at similar frequencies across the tree species while *Pseudopestalotiopsis* sp. 1, *Colletotrichum* sp. 3, and *Diaporthe* sp. 1 are disproportionately associated with *C. elastica, L. seemannii,* and *A. excelsum*, respectively. We experimentally confirmed pathogenicity for 58% of isolates tested, including some of the isolates in the aforementioned OTUs. Our results are consistent with growing evidence that phytopathogens with broad host ranges are common in tropical forests, but also suggest that host-generalist phytopathogens can contribute to observed patterns of conspecific negative density dependence by exhibiting host preference in the form of host affinity and operating as effective specialists.

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Cepas de *Calonectria* spp. aisladas de *Virola nobilis*: morfología, crecimiento y patogenicidad

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Virola nobilis, ha sido objeto de estudio debido a su importancia ecológica, pues sus frutos son ricos en proteínas, lípidos y azucares, y son alimento para la vida silvestre. Investigaciones anteriores se han enfocado en la presencia de hongos patógenos en *V. nobilis* como los responsables de valores de mortalidad elevados en plántulas que crecen cerca de los árboles de esta especie. Estos estudios señalan a *Calonectria* spp. como uno de los hongos con más frecuencia y el causante de la mayor mortalidad en plántulas recién germinadas. Este hongo de la familia Nectriaceae, incluye aproximadamente 20 géneros de importancia socioeconómica y se distingue de los demás por su relevancia como patógenos vegetales en cultivos forestales, agrícolas y hortícolas frecuentemente aislado en climas tropicales. Nuestro objetivo es caracterizar la morfología, crecimiento y patogenicidad de cepas de *Calonectria* spp. en *V. nobilis*. Para esto tomamos en cuenta siete cepas de *Calonectria* spp. previamente aisladas de tejido de tallo y ápice de plántulas de *V. nobilis*. Las cepas de *Calonectria* spp. en estudio están distribuidas en tres complejos de dicho género fúngico como lo son: *C. spathiphylli, C. cylindrospora* y *C. brassicae*. Realizamos experimentos de patogenicidad de las cepas de *Calonectria* spp. en hojas de *V. nobilis*; así como estudios de morfología y curvas de crecimiento de cada cepa. Nuestros resultados señalaron que hubo una correlación positiva entre la tasa de crecimiento y la patogenicidad, pero interesantemente hubo una correlación negativa entre la longitud de las esporas y la tasa de crecimiento.

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Caracterización de genes de resistencia en *Virola nobilis* de la isla Barro Colorado: Hacia una mejor comprensión de la dinámica poblacional

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Virola nobilis es una especie de árbol tropical, modelo para expandir la teoría ecológica de la dependencia de densidad negativa conespecífica (DDNC), porque ha demostrado tener una menor posibilidad de supervivencia en las plántulas cuanto más cercanas estén de los árboles de su misma especie. Estudios anteriores han evidenciado cómo los patógenos pueden especializarse a genotipos específicos y afectar el desarrollo de las plántulas en suelo materno, por lo que en conjunto con los genes de resistencia (GR), ambos factores influyen en la dinámica y la diversidad de las comunidades de las plantas tropicales. Con el objetivo de identificar la variación en los GR de *V. nobilis* en una parcela de 50 ha en la isla Barro Colorado (BCI), buscamos GR en los transcriptomas de raíz de 93 plántulas provenientes de once árboles madres, usando como referencia 215 GR anotados previamente para *V. nobilis*. Basado en esto, se seleccionaron los GR con una alta expresión génica y variabilidad alélica en la población de BCI. A partir de esta selección de genes, se diseñará sus cebadores (primers) para caracterizar la variación genética en 213 individuos de la población de BCI. Por medio del análisis integral de las tasas de crecimiento, ubicación y edad de los árboles censados a largo plazo, junto con los datos genéticos poblacionales, se busca comprender cómo la diversidad genotípica en los GR se relaciona con la dinámica poblacional de *V. nobilis* en BCI.

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Is there turnover in fungal pathogens from the forest floor to canopy and across ontogeny? Implications for the role of phytopathogens in the maintenance of forest diversity

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Fungal phytopathogens are ubiquitous in tropical forests and are important drivers of the maintenance of plant diversity. Fungal community composition can change across abiotic gradients as fungi are adapted to different environmental conditions. Fungal interactions with host plants can also shift as both organisms respond to abiotic stressors. However, little is known about how fungi are distributed from the forest floor to the canopy and across associated abiotic gradients. Utilizing STRI's canopy access crane in the seasonally dry forest of Parque Natural Metropolitano, we examined fungal pathogens of understory and canopy leaves of three locally common tree species. We hypothesized that changes in humidity, temperature, and UV radiation across the strata influence the relative abundances of strata-wide operational taxonomic units (OTUs) and genera, and taxonomic groups restricted to a stratum. Specifically, we predicted the relative abundances of strata-wide OTUs and total OTU richness would be lower in the canopy as only specialized fungi are able to thrive under those harsh conditions. To test this, we isolated putative pathogens from symptomatic understory and canopy leaves and are identifying the fungal isolates to genus and assigning them to OTUs using the universal fungal barcode ITS. Approximately 70% of OTUs are shared between the understory and canopy. The richness of OTUs is consistent in the canopy and understory; however, the strata have different dominant OTUs, and OTU evenness is lower in the understory. Considering the vertical distributions of the 13 observed genera, five occurred in both strata, including the two most common (*Colletotrichum* and *Diaporthe*), while eight were unique to either understory or canopy. Our results suggest that, despite strata-wide OTUs, fungal communities in the understory and canopy differ. This has implications for understanding disease dynamics in tropical forests, including pathogen sharing between adult and juvenile conspecifics. Future research will determine whether fungi are evolving to tolerate the extreme abiotic conditions in the canopy and examine the role dispersal plays in shaping fungal community composition and pathogen sharing across vertical gradients in forests.

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Achy Breaky Hearts: Investigating microbial-driven internal decay in tropical trees

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Tree death plays a crucial role in forest dynamics, influencing community composition, carbon storage, and ecosystem health. The contribution of fungal-caused disease to tree mortality rates is key to forest biodiversity and health under current and future climates. We are documenting the presence and magnitude of microbial-driven internal decay of heartwood in living trees (heart rot) and external indicators of tree health. Following the work of Gilbert et al. (2016), we are using non-invasive sonic tomography to assess internal decay for approximately 1,400 trees, representing 172 species, in Barro Colorado Island's 50-ha forest dynamics plot. For all trees, we are assessing decay at a height of 100 cm and, for a subsample of trees, we are also assessing decay at a height of 20 cm. We aim to quantify the community-wide prevalence of heart rot, changes in cross-sectional percent decay at the individual level over time, interspecific variation in susceptibility to heart rot, and the distribution of heart rot decay throughout the trunk. Heart-rot causing pathogens can enter trunks through roots; thus, we hypothesize that the likelihood and magnitude of decay is greatest near the trunk base. We also predict that interspecific variability in vulnerability to heart rot is tied to tree traits including lifespan, wood density, and shade- and drought-tolerance. Our preliminary results indicate that the community-wide prevalence of heart rot is at least 43% based on measurements made at two heights (n = 93), with decay only detected at either 20 or 100 cm for 21.5% and 7.5% of these trees, respectively, and rot detected at both heights for 14% of trees. Considering the 184 trees measured at 100 cm to date, 25% had detectable rot at that height and, of those, 26% had rot exceeding 50% of the cross-sectional area. Our preliminary results indicate heart rot is ubiquitous in tropical forests, but prevalence and magnitude vary across tree species, and that infection commonly begins belowground and is more frequently detected near the trunk base. Our study is ongoing. The complete dataset will shed light on patterns of pathogenic heartwood decay within living trees, with implications for understanding the interplay of microbial-driven disease, tree mortality, and forest community dynamics.

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Achy Breaky Hearts: Investigando la pudrición interna mediada por microbios en árboles tropicales

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La muerte de los árboles juega un papel crucial en las dinámicas forestales, influyendo sobre la composición de la comunidad, el almacenamiento de carbono y la salud del ecosistema. Las enfermedades causadas por hongos son una causa importante de esta mortalidad. Estamos documentando la presencia y magnitud de la descomposición microbiana en el duramen de árboles vivos (pudrición del corazón), e indicadores externos de su salud. Siguiendo el trabajo de Gilbert et al. (2016), evaluamos la descomposición interna de aproximadamente 1,400 árboles, que representan 172 especies, en la parcela de dinámica forestal de 50 ha de la isla Barro Colorado mediante tomografía sónica, una tecnología no invasiva. Para todos los árboles, evaluamos la descomposición a una altura de 100 cm, y para una submuestra de estos también evaluamos la descomposición a una altura de 20 cm. Nuestro objetivo es cuantificar la prevalencia de la pudrición del duramen a escala de comunidad, los cambios a lo largo del tiempo en el porcentaje de pudrición transversal a nivel individual, la variación interespecífica en la susceptibilidad a la pudrición y su distribución en el tronco. Los patógenos que causan la pudrición del corazón pueden ingresar a los troncos a través de las raíces; por lo tanto, planteamos la hipótesis de que la probabilidad y magnitud de la descomposición es mayor cerca de sus bases. También predecimos que la variabilidad interespecífica en la vulnerabilidad a la pudrición interna está ligada a rasgos de los árboles como la edad, densidad de la maderay tolerancia a la sequía y sombra. Nuestros resultados preliminares indican que la prevalencia de pudrición interna en toda la comunidad es de al menos 43% según las mediciones realizadas en dos alturas (n = 93), y la pudrición solo se detectó a 20 o 100 cm para el 21,5% y el 7,5% de estos árboles, respectivamente, y se detectó pudrición en ambas alturas en el 14% de los árboles. Considerando los 184 árboles medidos a 100 cm hasta la fecha, el 25% tenía podredumbre detectable a esa altura y el 26% de estos tenía pudrición superior al 50% del área del plano transversal. Se observa que la pudrición del corazón es omnipresente en los bosques tropicales, pero la prevalencia y la magnitud varían por especie, y que la infección comúnmente comienza bajo tierra y se detecta con mayor frecuencia cerca de la base del tronco. Este es un estudio en curso para el cual el conjunto de datos completo permitirá más comprensión sobre los patrones de descomposición interna en árboles vivos, y la interrelación entre las enfermedades microbianas en estos, su mortalidad y las dinámicas a nivel de comunidad.

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Patrones de abundancia en insectos que se alimentan de semillas de huéspedes específicos potencialmente competidores

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Los insectos que se alimentan de semillas de huéspedes específicos son una fuente importante, pero poco estudiada, de mortalidad de semillas en los bosques tropicales. Se sabe poco sobre las interacciones entre diferentes especies de estos insectos, que podrían competir por los mismos recursos finitos, ya sea a nivel de árbol individual o de fruto individual. Recolectamos frutos y semillas de especies de árboles con depredadores de semillas específicos de huéspedes conocidos y criamos insectos a partir de los frutos. Sobre la base de este material, presentamos patrones en la abundancia y coexistencia de insectos que se alimentan de semillas de huéspedes específicos en todo BCI.

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How does nutrient content, fruit removal rate and risk of attack shape fruit defense?

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Fruit traits mediate interactions with not only frugivore seed dispersers but also seed predators and other antagonists, leading to a trade-off in the traits that attract dispersers versus traits that deter antagonists. We tested hypotheses on which fruits need to be defended the most. Defense trade-off hypotheses propose either an increase in defense with increased nutrient content (nutrient-toxin titration model) which likely deters frugivore dispersers or reduced defense as higher nutrients might lead to faster removal rates (removal rate model). We estimated fruit removal rates across 6 Psychotria species by tracking individual fruit persistence. We tracked fruits on five to seven open and bagged infructescence every two days. We checked if the 'open' fruits were removed, likely by frugivores, and for the bagged fruits if they were dropped or damaged. Fruits that fell in the bags were checked for damage, and a subset for seed damage to assess risk of damage. We assessed fruit persistence rates using Kaplan–Meier survival estimates. Bagged fruits persisted longer than 'open' fruits across all the species except one which had low persistence in both. Preliminary analyses indicate a difference in fruit removal rates in at least two species, measured as hazard ratios. We are currently quantifying nutrient content across species as relative concentrations of lipids, sugars, and amino acids. We will quantify fruit toxicity through bioassays using fungal species isolated from Psychotria seed and leaf tissues.

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Incertidumbre en ecuaciones alométricas de monocultivo aplicadas a cultivos mixtos de árboles nativos en Panamá

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El componente forestal representa un aporte sustancial en la captura de dióxido de carbono (CO2), así, para estimar la capacidad de los bosques naturales y las plantaciones forestales de capturar CO2, es necesario el desarrollo de herramientas confiables para tal fin. Los objetivos de esta investigación fueron estimar la biomasa aérea de tres especies nativas (*T. amazonia, D. retusa, P. quinata*), generar ecuaciones alométricas específicas para especie por tratamiento y determinar la incertidumbre al utilizar ecuaciones monoespecíficas en parcelas mixtas. Se realizó un muestreo destructivo de las especies de interés, así, se cosecharon un total de 81 árboles en un rango de diámetro basal (DB) desde 3,60 hasta 32,50 cm, alturas desde 1,60 hasta 19,20 m y diámetros a la altura del pecho (DAP) desde 0.00 cm (*D. retusa* y *P. quinata*) hasta 35.70 cm (*P. quinata*), categorizados estos en nueve tratamientos en función de cómo estaban plantados (monocultivos y mezclas); la biomasa estimada varío desde 0.35 kg/árbol (*P. quinata*) hasta 436.13 kg/árbol (*T. amazonia*). No se detectan diferencias significativas entre los tratamientos para ninguna de las variables evaluadas: altura, diámetros y biomasa; sin embargo, los datos brutos de biomasa aerea (kg/árbol) mostraron una tendencia a mayor acumulación en *T. amazonia*. Con la evaluación del modelo lineal ln(βa) = a+b×ln(x) con 10 entradas de variables, donde ln(x) fue DB, DAP y altura tanto únicas como en combinación, se obtuvieron ecuaciones alométricas para multiespecies y cada especie por tratamiento, seleccionadas mediante el Criterio de Información de Akaike (AIC). En multiespecies, se obtuvieron los mejores coeficientes correlacionales (R2 ajustado) de 0,98 y 0,97, y en cada especie por tratamiento se obtuvieron correlaciones superiores a 0,96. El cálculo del error relativo arroja que el uso de ecuaciones monoespecíficas aplicadas a parcelas mixtas provoca altos sesgos en las estimaciones entre 25% y 75%. De este modo, este trabajo contribuye a ampliar el conocimiento de tres especies arbóreas importantes en el esquema de reforestación nacional y su uso para restauración y captura de CO2.

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Exploring the biomineralization of silica bodies in *Selaginella*

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The study of biomineralization processes in plants is essential for understanding the relationship between morphophysiology and adaptations to different environments, climatic fluctuations, and evolutionary pressures. In other organisms, such as diatoms, silica biominerals focus light, while in marine sponges, silica spicules exhibit light-guiding properties similar to those of artificial optical fibers. However, it is still unknown whether silica biominerals would serve the same optical function in plants. Although studies on biominerals have focused on angiosperms, Selaginellas, with their high silica content (0.69 to 11.21% dry weight), offer a unique perspective to assess the optical effect of silica. Selaginella, with a geological history dating back 350 million years, possesses unique characteristics among vascular plants. *Selaginellas* are cosmopolitan, with centers of diversity in tropical regions, and they inhabit diverse environments ranging from cloud forests to semi-desert communities. Some species are pioneers in colonizing environments, growing on rocks with mosses, while rothers are reviviscents plants in xerophytic environments. In contrast to angiosperms, dorsal epidermal cells have large chloroplasts or a dimorphic ultrastructure (bizonoplast) and a high density of small silica bodies (0.5 to 2 microns) on their surface. These characteristics suggest that the optical effects of silica could be localized at the cellular level. The “window” hypothesis postulates that silica bodies facilitate the capture and transmission of light by redirecting sunlight towards chloroplasts. We will assess the effect of a gradient of forest cover (a significant indicator of light radiation intensity) on the density and size of silica bodies on the leaf blade.

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Diurnal variation in photosynthetic responses of *Calophyllum inophyllum* to temperature shifts: Implications for tropical species adaptation

Presenter: Juan Camilo MEJíA MEDINA

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This study investigates diurnal fluctuations in photosynthetic variables, including maximum rates of carboxylation (Vcmax) and electron transport (Jmax), as well as net CO2 assimilation (Anet), in response to temperature variations in tropical tree species *Calophyllum inophyllum*. We measured short-term CO2-response curves of photosynthesis to determine Vcmax, Jmax, and Anet, and rapid temperature-response curves to determine the optimal temperature (Topt) and photosynthetic rate at the optimal temperature (Aopt). Additionally, we conducted heat tolerance analysis to explore variations in leaf critical temperature (Tcrit) and the temperature at which photosystem II capacity is reduced by 50% (T50). Our results revealed significant diurnal variation in photosynthetic capacity, with a notable 21% decrease in Vcmax, a 17% decrease in Jmax, and a 37% decrease in Aopt in the afternoon relative to the early morning. However, Topt exhibited a slight decrease of only 2.4% in the afternoon relative to the early morning. Heat tolerance parameters remained relatively stable between morning and afternoon, with Tcrit values of 48.4°C and 48.5°C, and T50 values of 50.7°C and 51.0°C, respectively. The afternoon decline in photosynthetic capacity may stem from reduced CO2 supply, which may result from afternoon stomatal closure and decreased CO2 transport within the leaf. These findings emphasize the critical importance of considering diurnal dynamics in photosynthesis and stomatal conductance, as Vcmax and Jmax are key parameters in models projecting the future of the global carbon cycle. Further investigation into diurnal responses in photosynthetic capacity, particularly in tropical species, is essential for advancing our understanding of plant physiological adaptations to environmental fluctuations and to reduce uncertainty in estimates of tropical forest carbon uptake.

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Nutrient efficiencies in three tropical species as part of the Agua Salud Research Project

Presenter: Maria Alejandra GALLEGOS KOYNER

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Understanding the silvicultural characteristics of tropical tree species is crucial for implementation of reforestation projects in the tropics, especially in low-fertility areas. In moist tropical areas, major factors affecting biomass production include nutrients, particularly phosphorus (P), nitrogen (N) and potassium (K) which are the focus in this study. In Panama it has been observed that some species grow rapidly on soils low in P availability. *Terminalia amazonia* has been found by Condit and colleagues to be associated with low P soils and Mayoral et al. (2017) it to have far greater biomass accumulation in the Agua Salud experiment than other planted trees. In this study we assess nutrient use strategies as a potential explanation allowing *T. amazonia* to build so much more biomass than other species in low-fertility sites. In the Agua Salud plantations, we extracted tissue sections of monocultures of *T. amazonia, Dalbergia retusa* and *Pachira quinata*, including bark tissue, wood from the stem, leaves, and branches. From these tissues, we extracted nutrient concentrations to determine nutrient use efficiencies (NUE), stocks and retranslocation percentages in leaves with dehiscence. Looking at results of NUE and retranslocation of nutrients in the leaves, together with leaf longevity can help understand mechanisms used by *T. amazonia* to survive and thrive in Agua Salud and similar sites. This poster will present an ongoing analysis on how nutrient use efficiency and retranslocation of these species can play a role in biomass production differences in low-fertility areas.

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Causal relationships between tree functional traits, assimilation, and life history strategies

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Minh Chau N. HO and Annette M. OSTLING

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Linkages between functional traits and an organism's demographic rates are a key component of the functional ecology framework. Much of the relationship between traits and species' differences in growth, survival, and reproduction is thought to emerge from underlying physiological mechanisms but thus far the vast majority of studies examine trait-performance relationships phenomenologically. Establishing more mechanistic relationships between traits and organism's performance would strengthen our understanding of trait-performance relationships. Here we propose the use of causal models to examine the relationship between leaf mass per area (LMA), leaf nitrogen content (Nmass), wood density (WD) and species' positioning on the growth-mortality trade-off, mediated by species' saturating photosynthetic rate (Amax). We predict that LMA and Nmass will have a causal influence on Amax, and that Amax and WD will have a causal influence on species' positioning on the growth-mortality trade-off. For 30 coexisting tree species in Panama, Nmass had a positive causal influence on Amax, while LMA and WD had causal influences only on species' positioning on the growth-mortality trade-off; LMA did not have an influence on Amax. Species with fast growth rates and high mortality rates had higher assimilation rates (Amax), although this relationship was not always significant, and lower wood densities. Higher assimilation rates are achieved with higher leaf nitrogen content (Nmass), but not through higher leaf area (lower LMA) as expected. These preliminary results suggest that LMA seems to have an influence on growth and mortality through some other mechanism besides light interception for photosynthesis, and further research is needed to understand how LMA influences species' growth and mortality. Additionally, these results suggest that the assumed physiological mechanism underlying trait-performance relationships may be different than expected, and more studies on these linkages are necessary.

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Coexistence through life history variations in an explicit patch age model

Presenter: Jon R. STAGGS

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A mechanistic understanding of coexistence remains a prominent challenge in ecological theory. Classical hypotheses in forest community ecology propose that disturbances and patch dynamics enable coexistence among species with life history strategies ranging from gap specialist to shade tolerant, often called “successional niche” differentiation. However, prior mathematical models have not fully delineated which life history strategies variation can promote coexistence under disturbance and succession. We build upon a PDE model that integrates explicit patch aging with disturbances and within-patch competitive dynamics. In particular, we incorporate the age of reproductive maturity as a life history trait. We investigate trade-offs against the age of reproductive maturity under two types of density dependence, namely on reproduction and mortality. In both cases, we identify multiple trade-offs against the age of first reproduction including offspring survival to adulthood, sensitivity of offspring survival to competition, and adult survival, that all enable coexistence. Many of the results can be derived analytically and in the less tractable cases, we conduct numerical simulations. We use the BCI census data to look in particular for the occurrence of an interspecific tradeoff between age of first reproduction and offspring survival to adulthood, which could arise from the often-reported growth-survival tradeoff in saplings among tree species that do not differ drastically in their size of reproductive maturity. Indeed we find support for this tradeoff among tree species on BCI, suggesting it could play a role in competitive coexistence there. We also find our incorporation of an age of first reproduction leads to cycling in total density in some regions of parameter space (especially high reproduction). We are investigating if this is an essential feature of this addition, or if cycles disappear when the age of first reproduction is modeled as a distribution rather than as one specific value.

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Re-examining the phylogenetic structure of the BCI forest community reveals overdispersion across spatial scales

Presenter: Ryan R. HERNANDEZ

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Understanding the phylogenetic structure of forest communities can give insight into the evolutionary history of the community and the ecological processes that help shape it. Some patterns that may be present in such communities are phylogenetic overdispersion or clustering. Phylogenetic overdispersion is when species are less phylogenetically related than expected and can be an indicator of a history of competitive exclusion in a community. On the other hand, phylogenetic clustering is when species are more phylogenetically related than expected and can be an indicator of ecological processes such as habitat filtering. This study analyzes patterns of phylogenetic overdispersion or clustering in the tree community of the Forest Dynamics Plot on Barro Colorado Island (BCI). This was done by dividing the BCI plot into quadrats of four different spatial scales (10 x 10m, 20 x 20m, 50 x 50m, and 100 x 100m) and calculating the net relatedness index (NRI) and nearest taxon index (NTI) of the species present in the quadrats using a pairwise phylogenetic distance matrix, with 270 tree species being included in the study. Prior work has emphasized the importance of null model choice. In this study we used the favored constrained null in which the frequency of occurrence in quadrats of each species is preserved. We simulated this null to create the expected distribution of mean NRI and NTI values across quadrats for significance testing. This contrasts with prior studies that inappropriately used a t-test to compare observed mean NRI and NTI across cells with their expectation in the null, namely 0. The t-test is too conservative in this context due to correlation in NRI and NTI values across quadrats under the constrained null. Preliminary results using this method indicate that there is evidence of overdispersion across all spatial scales, i.e. co-occurring species more distantly related than expected. This contrasts with prior results for BCI where overdispersion was only found at the smallest spatial scales, and to a weaker extent.

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The emergence of phylogenetic clusters in stochastic niche forest communities

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Phylogenetic signals can help reveal the ecological and evolutionary processes driving community assembly. However, these patterns have not been revised given the recent advances in community assembly which have shown the emergence of species clusters on a trait axis via competition. We propose that there may be similar patterns of multiple clusters in the phylogeny. This differs from prior metrics of phylogenetic clustering or overdispersion, which only measure the degree of relatedness in the community. We use a 'stochastic niche' community assembly model combining stochastic birth, death, and immigration along with niche differentiation processes. We apply this model to different regional pools of species whose trait values are generated from different modes of trait evolution (i.e., more/less conserved trait evolution) on the BCI phylogenetic tree. We then determine the patterns of phylogenetic clustering in these communities using a novel algorithm for cluster detection in networks by incorporating species abundance and phylogenetic information. We find that there are multiple phylogenetic clusters and that the pattern of phylogenetic clustering is strongest when the trait is evolved in a conserved way on the phylogeny. Thus, communities selected by environmental filtering (leading to conserved traits) can have distantly related species coexisting in multiple clusters. Using our algorithm, we can quantify the variation in the strength of phylogenetic clusters arising from different mechanisms of community assembly (environmental filtering, competition, and stochastic birth/death processes.) This emergence of multiple clusters from conserved traits contrasts with prior empirical studies on BCI and other forests' data, which would expect simply more phylogenetically related species in a community selected by environmental filtering. Thus, our study provides a revision of community phylogenetic pattern expectations, as well as a new tool for detecting these phylogenetic patterns in forest communities like BCI and other ForestGEO sites.

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The impacts of long-term soil warming on nitrogen-fixation in tropical understory trees in Panama

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Climate change is predicted to raise above-ground temperatures by 3.5°C in tropical ecosystems and global soil temperatures by 4.5 ± 1.1°C within the 21st century. Tropical soil warming has been shown to cause free-living soil microbial community shifts towards thermophilic taxa, decrease microbial diversity, and increase soil CO2 efflux. The lowland tropical rainforest of Barro Colorado Island (BCI) in Panama contains many species of nitrogen-fixing understory trees that form symbioses with these soil microbes to produce bioavailable nitrogen (N). The potential influence of long-term soil warming on symbiotic N-fixation is not well understood, and studies involving long-term soil warming in the tropics are extremely limited. To elucidate these interactions, plots of three N-fixing and three non-N-fixing understory tree species were grown on BCI utilizing the soil warming infrastructure provided by SWELTR. Following seven years of soil warming at 30°C, leaves were collected and currently, the processing of samples is ongoing. Levels of N-fixation will be measured through obtaining 15N and 13C natural abundance ratios using IRMS. In the following study, we predict that (H1) exposure to long-term soil warming will increase levels of symbiotic N-fixation, and (H2) due to an increased input of bioavailable N, N-fixing species will have higher survival rates and biomass in comparison to non-N-fixing species, and that this effect will be more pronounced in heated plots. This project aims to improve our understanding of the responses of N-fixing understory trees to long-term soil warming, with potential implications for ecosystem resilience in the face of climate change.

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Past human mobility in the Lower Central American Landbridge: preliminary results

Presenter: Yajaira NUNEZ CORTES

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Past human groups on the lower Central American land bridge (southern Nicaragua to northern Colombia) sustained a complex interplay with their surrounding environments, yet we still have a limited understanding of the diversity and variation of residential mobility through time and space. This knowledge is critical to understand how these societies colonized tropical habitats and thrived to become complex societies. This area is uniquely characterized by endemic development of linguistically and genetically related groups which approximately seven centuries before the European contact period witnessed the arrival of Mesoamerican migrant populations from the north. The last 2000 years of pre-Columbian history see the emergence of variable sociopolitical complex societies that arose in the heterogenous environments of the Lower Central America Landbridge. This context of local development and endemic processes, with active contact followed by human migration, is the perfect basis to study the degrees of mobility and the potential effects of large-scale movements of migrant populations into the area. We present preliminary data on a multi-isotope program (strontium, oxygen, and lead) for the establishment of an isotopic baseline that will be later contrasted to past human populations from archaeological sites in Panama and Costa Rica.

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Archaeology of childhood: isotopic approaches to breastfeeding and weaning practices in three pre-columbian panamanian populations.

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In the past, breastfeeding and weaning practices played a crucial role in the survival of populations. In fact, the well-being of children can be used as an indicator of the overall population's health status and can reveal shifts in the population's demographics, mortality rates, and prevalence of illnesses. The analysis of the isotopic composition of carbon (δ13C) and nitrogen (δ15N) preserved in the bone collagen has been used to identify the duration of breastfeeding and the introduction of solid foods in children's diet. This research aims to reconstruct the infant diet of pre-Columbian populations of the central region of Panama, focusing specifically on breastfeeding and weaning practices. For this purpose, 44 non-adult individuals from the osteological collections from Cerro Juan Díaz, Sitio Sierra and Cerro Mangote have been analyzed for dietary isotope composition. These collections are currently under the care of the Archaeology Laboratories at the Smithsonian Tropical Research Institute (STRI) in Panama. The study of the individuals in this sample provided insight into cultural practices associated with breastfeeding and the possible differences or similarities between the populations.

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Fossil Leaves from the Gigante Peninsula

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157 fossil leaves were recently found at the Gigante Peninsula. The study of these fossils can provide evidence to document the vegetation changes of the forest from the Barro Colorado Nature Monument (BCNM). Fossils from the Pleistocene epoch represent an invaluable resource for reconstructing past environments and understanding the dynamics of tropical ecosystems during periods of climatic variability. So, I processed the fossil samples following standard techniques to characterize the leaf physiognomy, then I separated them into morphotypes. Using the fossil leaf physiognomy. I also compared the information available of the modern flora from BCNM vs fossil flora to estimate changes in diversity through geologic time. Taxonomic identification of fossil leaves indicates the presence of ancestral taxa (e.g. *Apeiba*), often endemic to tropical regions, suggesting past biogeographic connections and evolutionary trajectories. Furthermore, comparative studies with modern plant communities will facilitate interpretations of paleovegetation structure and ecosystem dynamics on the Gigante Peninsula.

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A stylistic and typological analysis of the poorly known La Mula pottery from Cerro Juan Díaz first settlers

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La Mula pottery (c. 200 BCE – 200 CE) is one of the earliest ceramics in southern Central America. Found to date at only a few sites, among them Isla Carranza, Sitio Sierra, La Mula-Sarigua, La India and Las Huacas, it is known from small scattered samples. Excavation conducted at Cerro Juan Díaz (near modern Chitre/ Los Santos) between 1998 and 2000 revealed hundreds of well-preserved decorated sherds, both painted and modeled, identified at the time by Dr. Richard Cooke as the most important sample known of La Mula pottery. Due to its early age, the study of this collection is essential to reveal cultural links between Pre-Columbian groups in the region over time and improve our understandings of Cerro Juan Díaz's first settlers. This poster will introduce the Cerro Juan Díaz site and the Operation 5 context that revealed the oldest site occupation where the La Mula pottery was found. It will examine the preliminary results from the ceramic analysis currently underway. Finally, it will bridge with my broader doctoral project that seeks to explore if Cerro Juan Díaz's 1,500 years of occupation acted as a local, regional or extra-regional place of worship, making it one of the few sites that remained in people's long-term memory thus far identified in southern Central America.

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Digitization and morphometric analysis of modern pollen grains of the Rosaceae family

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The Rosaceae is an Angiosperm family with a cosmopolitan distribution, presenting three subfamilies (Spiraeoideae, Rosoideae, Dryadoideae) with 90 genera and 3000 species. Rosaceae has pollen polymorphism, presenting tricolporate, tetracolporate and hexacolporate forms as well as a difference in exine thickness, sculpture (i.e., rugulate, striate) and pollen size. In addition, its evolutionary history represents necessary information to understand the Andean ecosystems. The Graham collection has 65 genera and 185 modern species obtained from herbaria, being one of the most complete collections of Neotropical Rosaceae. The digitization of this collection will become an identification tool, improving the taxonomic resolution of pollen grains and contributing to paleoecology studies through high-resolution microscopy. Confocal technique captures three-dimensional morphology without destroying the grain, maintaining morphological information digitally, so that modern specimens can be compared with fossils and improve their interpretations.

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Efecto del afloramiento en la abundancia y prevalencia de parásitos en peces serránidos del golfo de Panamá

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Las interacciones parásito-hospedero se han estudiado en muchos aspectos. Sin embargo, poco se conoce sobre el efecto de fenómenos como el afloramiento en estas dinámicas. Este trabajo buscó conocer cómo este evento incide en dichas interacciones, en peces de interés comercial. Entre 2021 y 2023 se colectaron 238 meros de las especies *Cephalopholis colonus, C. panamensis* y *Epinephelus labriformis*, alrededor del archipiélago de Las Perlas, golfo de Panamá. Se realizaron procesos de disección estándar y revisión de las partes externas de los peces en busca de parásitos, los cuales fueron preservados en etanol al 70%, 95%. Nuestros resultados mostraron un incremento en la abundancia parasitara durante afloramiento ($p= 0.008$) y una diferencia marcada por las especies de hospederos ($R2= 0.49$, $p<0.001$). Se encontró una elevada presencia de *Hatschekia* spp. en *C. colonus*, así como de metacercarias en esta especie y en *C. panamensis*. Mientras que, *E. labriformis* mostró un elevado número de monogéneos de la familia Diplectanidae, así como digéneos de la familia Didymozoidae y nematodos del género *Philometra* spp. La relación parasitaria en los serránidos muestra estar más ligada a los aspectos filogenéticos que a los ecológicos, mostrando mayor similitud de parásitos entre las especies del género *Cephalopholis*, que entre *C. panamensis* y *E. labriformis*, quienes comparten nicho y presentan una dieta similar. Este estudio presenta por primera vez en nuestro país, información clave para sentar las bases y comprender cómo el afloramiento puede influir en las poblaciones parasitarias; en este caso, en peces de interés comercial.

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Effecto de antioxdantes en la capacidad fotosíntetica de *Pocillopora verrucosa*, como propuesta para la conservación de arrecifes de corales

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Los antioxidantes son moléculas que protegen a organismos contra el daño oxidativo causado por los radicales libres (por ejemplo, especies reactivas del oxígeno, ROS). Un desequilibrio grave entre la generación de ROS y la protección antioxidante a favor de las primeras conduce al estrés oxidativo, una condición fisiológica en la que se produce un daño oxidativo excesivo en las biomoléculas (por ejemplo, lípidos, proteínas y ADN) que, en última instancia, conduce a la muerte celular y a enfermedades. En las asociaciones endosimbióticas entre algas y Cnidarios, las algas simbiontes generan mayores cantidades de ROS que los tejidos del hospedador, debido a su naturaleza fotosintética que genera hiperoxia durante la luz solar. Se ha demostrado que el mantenimiento del equilibrio redox es un importante mecanismo de aclimatación a los cambios de temperatura, mientras que el desequilibrio redox (ROS > antioxidantes) está íntimamente relacionado con el proceso de blanqueamiento de los corales. Sobre la base de estos hallazgos, la hipótesis del presente estudio es: la exposición a combinaciones de antioxidantes específicos mejorará el equilibrio redox en los corales y sus endosimbiontes promoviendo una mejor resistencia y resiliencia en cuanto a los desafíos asociados al blanqueamiento. Realizamos una serie de experimentos toxicológicos agudos cortos durante el mes de febrero del 2023. Tres colonias de *Pocillopora verrucosa* fueron colectadas en 3 sitios diferentes en el Archipielago de las Perlas (Islas Mogo Mogo, Saboga y Contadora) y transferidas a las instalaciones experimentales de los laboratorios marinos de Naos, STRI. Estas tres colonias (una de cada sitio) se utilizaron para generar un total de 108 nubbins (36 por colonia), a los que administramos diferentes concentraciones de L-ascorbato de sodio (Vit C) y N-acetil-L-cisteína (NAC). Los nubbins se mantuvieron en suspensión por hilos de nylon, y se mantuvieron en varios tanques experimentales independientes de 1 litro abastecidos con agua de mar, irradiación, temperatura y salinidad constante. Para evaluar la salud y el rendimiento fotosintético de los corales medimos el potencial FV/FM con un fliorometro subacuatico, Diving-PAM. Para contrastar esta medición cuantificamos las proteínas, zooxantelas, y clorofila en el tejido de coral de cada fragmento; mediante el uso de un espectrofotómetro. Con este experimento esperamos evaluar el efecto de la suplementación con antioxidantes en la capacidad fotosintética de la principal especie formadora de arrecife del Pacífico Oriental Tropical y brindar información relevante para perfeccionar esfuerzos de conservación y repoblación en zonas afectadas por blanqueamiento de coral.

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Cambios en la eficiencia fotosintética de *Pocillopora* spp. en el Pacifico Este Tropical de Panamá ante el reciente fenómeno del Niño

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La costa pacífica de Panamá está dividida en dos grandes golfos, el golfo de Panamá (GoP) y el golfo de Chiriquí (GoC), los cuales presentan diferencias ambientales muy marcadas. Sin embargo, para ambos golfos la mayor cobertura coralina está representada por el género *Pocillopora* spp, del cual se pueden identificar dos linajes *P. grandis* (tipo 1) y *P. cf. verrucosa* (tipo 3). Debido al fenómeno del Niño (ENSO), que provoca el aumento en las temperaturas superficiales del océano, dicha cobertura se ha visto afectada por los eventos de blanqueamiento que causan la liberación de las zooxantelas y eventual mortalidad a consecuencia del estrés térmico. En meses recientes, incrementos en la temperatura superficial (±30 °C) han causado el blanqueamiento de *Pocillopora* en ambos golfos, y una mayor mortalidad de Pocillopora tipo 3 se ha observado en el GoP. Teniendo en cuenta lo anterior, nos planteamos las siguientes preguntas: (1) ¿Ocurren cambios en el estado de desempeño fisiológico de Pocillopora de ambos golfos con el aumento de la temperatura?, (2) ¿Incide el fenómeno de afloramiento sobre dicho desempeño fisiológico de los corales en el GoP? Para evaluar dichas preguntas, decidimos documentar la susceptibilidad al blanqueamiento en Pocillopora de ambos golfos a través de mediciones de eficiencia fotosintética (Fv/Fm) de colonias previamente marcadas e identificadas en sitios permanentes en cada golfo antes y durante el actual ENSO. Esta eficiencia fotosintética, es una medida de fluorescencia in situ del fotosistema II (PSII) de las zooxantelas del coral al recibir impulsos de luz y es un indicador del estado de desempeño fisiológico de colonias de coral. En base a lo anterior, esperamos observar una disminución en la eficiencia fotosintética de los corales del GoC debido a la ausencia de la temporada de afloramiento y por ende aumento del blanqueamiento y mortalidad de las colonias con la intensificación del ENSO. Por otra parte, para el GoP esperamos que las colonias sobrevivientes recuperen su eficiencia fotosintética cuando se regulen las temperaturas por influencia de las aguas frías del afloramiento. Sin embargo, es posible que con el cambio extremo de temperaturas los corales sufran afectaciones en su fotobiología y por ende su recuperación se prolongue posterior al tiempo de este estudio. No obstante, esperamos contribuir al entendimiento de la resiliencia y susceptibilidad de los linajes de *Pocillopora* ante estresores ambientales relacionados con el inminente cambio climático que pone cada vez más en peligro su supervivencia.

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Aumentos estacionales de clorofila podrían explicar las migraciones de grandes pelágicos en la región oeste de Coiba, Golfo de Chiriquí

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Los aportes de nutrientes pueden afectar todos los aspectos de la dinámica de las redes tróficas: los productores primarios en los ecosistemas están limitados por nutrientes, y el aumento en la oferta de recursos generada por estos aportes incrementa el crecimiento y la abundancia de los productores. La energía generada por los productores primarios se propaga a través de enlaces tróficos, generando efectos positivos de abajo hacia arriba en los consumidores. El Golfo de Chiriquí es conocido por sus condiciones oligotróficas cálidas que, paradójicamente, sostienen grandes especies migratorias como los tiburones ballena, mamíferos marinos y grandes depredadores. La fuente de la energía necesaria para sostener este rico ecosistema sigue siendo desconocida. Sin embargo, a través de mis estudios satelitales analizando datos desde el año 2003 al 2022, parece haber una marcada estacionalidad en los aumentos de clorofila en la región oeste de Coiba durante los meses de abril, mayo y junio. Estos picos de productividad primaria parecen coincidir con las migraciones de grandes pelágicos; sin embargo, desconocemos el mecanismo que los produce. Mis predicciones apuntan hacia dos posibles factores: upwellings debido al choque de ondas internas con la pronunciada batimetría de la zona, o aumentos de los nutrientes provenientes de fuentes terrestres a través de escorrentía. Para resolver esta cuestión, cuento con la ayuda del S/Y Eugen Seibold, un barco del Instituto Max Planck de Química, especializado en muestreos oceanográficos químicos. Con este velero, además de realizar cruceros para caracterizar la variabilidad estacional y regional del afloramiento a lo largo de las costas del Pacífico Tropical Oriental, estoy recolectando muestras de agua y plancton para el análisis de nutrientes e isótopos de δ18O y δ15N. Una vez tenga los resultados de esas muestras podré determinar la procedencia de estos subsidios de nutrientes, lo cual ayudará a entender el mecanismo que rige esta región oligotrófica.

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Respuesta celular ante procesos de estrés térmico y salino en *Pocillopora grandis* y *Pocillopora cf. verrucosa* del pacifico panameño

Presenter: Mariana L FERNÁNDEZ

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Los arrecifes de coral albergan una cuarta parte de las especies que habitan los océanos, pero debido al incremento de las temperaturas superficiales y otros factores de estrés que han estado atravesando, su salud y bienestar se encuentra cada vez más amenazada. En el Pacifico de Panamá grandes arrecifes de coral se encuentran situados en el golfo de Panamá y en el golfo de Chiriquí. En ambos golfos se pueden encontrar corales del género *Pocillopora* spp (*Pcf. verrucosa* y *P.grandis*) siendo estos los principales constructores de arrecifes en las áreas menos profundas. En el golfo de Panamá sucede el fenómeno de afloramiento en los primeros meses del año y toma lugar cuando el agua subterránea se transporta hacia la superficie oceánica, cambiando drásticamente la temperatura, salinidad y otros factores ambientales. En la actualidad se sugiere que el afloramiento en el golfo de Panamá pudiera estar protegiendo a los corales del calentamiento que se encuentra asociado con el cambio climático. Sin embargo, durante el más reciente fenómeno del Niño altas temperaturas causaron el blanqueamiento masivo primordialmente de *Pocillopora cf. verrucosa* en el golfo de Panamá. El objetivo principal de esta investigación es determinar y comparar la respuesta celular de *P. cf. verrucosa* y *P. grandis* provenientes del golfo de Panamá ante diferentes procesos causantes de estrés y posibles desencadenantes de blanqueamiento. Fragmentos de ambas especies fueron sometidos a tratamientos de temperatura extrema (i.e., alta y baja) combinados con salinidad ambiente y baja por un periodo de 18 horas. Luego del estrés ambiental, utilizamos pruebas de peroxidación lipídica como biomarcadores para evaluar el daño oxidativo en las células en el proceso de blanqueamiento de coral. La peroxidación lipídica es un proceso de reacciones en cadena en el cual moléculas de lípido se oxidan ante la presencia de especies reactivas del oxígeno liberadas por el simbionte en estado de estrés. Sin embargo, dicha relación de estrés oxidativo entre el simbionte y su huésped sigue siendo evaluada en el proceso de blanqueamiento coralino. No obstante, El daño celular por medio de la peroxidación lipídica ha sido documentado para distintas especies de coral ante la degradación ambiental funcionando como una herramienta para comprender la respuesta a nivel celular ante diferentes estresores ambientales. Con este estudio esperamos comprender el potencial de las pruebas de peroxidación lipídica como biomarcador de estrés oxidativo en corales del género *Pocillopora*, y analizar la susceptibilidad de cada especie frente a varios parámetros de estrés causantes de blanqueamiento.

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Exploring the effects of salinity and temperature stress on the physiology of *Pocillopora grandis* from the Panamanian Eastern Tropical Pacific

Presenter: Kyaralind VASQUEZ-LIRIANO

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Coral reefs provide shelter and nourishment for many marine organisms, as well as food and income for humans. Unfortunately, these ecosystems are degrading due to climate stressors. In the Eastern Tropical Pacific (ETP) region of Panama, coral reefs within the Gulf of Panama (GoP) and the Gulf of Chiriqui (GoC) experience distinct oceanographic conditions. In the GoP, corals experience a wide range of temperature and salinity fluctuations partially due to the upwelling that occurs during the dry season, which brings cold seawater to the surface and temporarily increases the salinity of surface waters. In contrast, the GoC does not undergo upwelling, resulting in comparatively stable temperature and salinity conditions. Based on these differences between the GoP and the GoC, we experimentally investigated the physiological effects of temperature extremes and salinity fluctuations on Pocillopora grandis (Type 1), one of the primary reef-building corals in the ETP, from each Gulf. We hypothesize that under high temperature conditions, corals from both Gulfs will experience a low concentration of protein and low abundance of photosynthetic symbionts. Under low temperature conditions, we expect a higher protein concentration and symbiont abundance in the GoP than the GoC. Lastly, under low salinity conditions, we also expect a higher protein concentration and symbiont abundance in the GoP than the GoC. To conduct our study, coral fragments were collected from three reef sites across the two Gulfs and were put in six acute stress treatments that combined different magnitudes of salinity and temperature. Following the experiment, we assessed the physiological response of the corals using the bleaching descriptors protein concentration and abundance of symbionts from coral tissue samples. With our results, we aim to illustrate how the combined effects of climate stressors can impact the resilience of Pocillopora corals from the Panamanian ETP.

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Exploring mesophotic coral reef diversity on a Caribbean seamount using environmental DNA

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Coral reefs, vital marine ecosystems, face increasing threats due to anthropogenic impacts. Monitoring the ecosystem's diversity and its changes is crucial for marine protection. While shallow coral reefs can be monitored by visual censuses, mesophotic coral ecosystems (MCEs), and especially those on seamounts, remain understudied due to limited accessibility. Nevertheless, these ecosystems harbor a vast diversity and could function as refuge habitats. eDNA metabarcoding is an innovative method for biodiversity assessment in which short DNA fragments of biological material, such as skin, mucous, blood, or feces are amplified, sequenced, and assigned to a taxonomic rank based on reference libraries to identify multiple species simultaneously. The application of eDNA metabarcoding is gaining importance in monitoring marine ecosystems and can enhance our understanding of potentially unique MCEs. In this project, we use eDNA metabarcoding to test whether pelagic and mesophotic benthic communities of coral reefs of 12 mile bank, a Caribbean seamount off of the Cayman Islands, are unique compared to shallow and mesophotic reefs on nearby islands using comparative eDNA metabarcoding. Samples of seawater and sediments of various sites spanning depths up to 50m will be analysed with three metabarcoding assays targeting metazoans (COI), fish (12S rRNA), and corals (ITS2). Richness (alpha diversity) and community composition (beta diversity) will be compared between sites and between depths. We will identify suites of taxa that are uniquely present on the seamount, highlighting the significance of seamounts as refuge habitats and their importance in conservation efforts. eDNA data, together with high-resolution maps of the seamount's habitats and topography, will provide foundational data on the poorly studied coral reefs of the seamount which can be the basis for conservation strategies and further ecosystem monitoring.

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Plasticidad de nichos tróficos en especies hermanas de peces separadas por el Istmo de Panamá

Presenter: Javiera MORA SCHEUER

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El cierre del Istmo de Panamá hace aproximadamente 3 Ma provocó la separación física de poblaciones de especies marinas, interrumpiendo el flujo genético y promoviendo procesos evolucionarios independientes a cada lado del istmo a causa de modificaciones ambientales. La evolución de las especies de peces arrecifales recién separadas por la formación del istmo (especies hermanas) ha sido muy estudiada. No obstante, aunque el rendimiento de los peces está estrechamente vinculado a los recursos disponibles, se sabe muy poco sobre hasta qué punto los peces hermanos han desarrollado comportamientos alimentarios o morfologías especializadas para explotar recursos alternativos. El objetivo de mi investigación es usar a las especies hermanas *Cephalopholis panamensis/ Cephalopholis cruentata* (carnívoros oportunistas) y *Abudefduf troschelii/ Abudefduf saxatilis* (omnívoros) como modelo para comprender la plasticidad de los nichos tróficos de peces arrecifales. Caracterizo la dieta a través de análisis visuales, incorporando el método gravimétrico para cuantificar los items alimenticios con el objetivo de determinar si hay diferencia en la posición y amplitud de nicho trófico de las especies hermanas y en la plasticidad alimenticia entre grupos tróficos diferentes (carnívoros e omnívoros). En Panamá los estudios de dieta de peces arrecifales son escasos, por tanto, mi investigación contribuye con datos pioneros sobre la dieta de especies que se encuentran abundantemente en los arrecifes y los mecanismos que promueven la plasticidad y evolución de nichos tróficos en peces con reciente divergencia alopátrica, los cuales están expuestos a sistemas productivamente diferentes. Entender esto es crucial para predecir la manera en que los organismos responderán a los cambios ambientales, cómo el cambio climático o la pérdida de hábitat.

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En busca de la especie en peligro crítico de extinción (Pristis pristis) en el POT de Panamá usando el ensayo altamente sensible, Digital Droplet PCR

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Los peces sierra (familia Pristidae) tiene un rol clave como depredador tope en los ecosistemas acuáticos que habita. Controlan la distribución y abundancia de sus presas, lo cual ayuda a mantener la estructura y el funcionamiento del ecosistema. El pez sierra de dientes grandes (*Pristis pristis*), es una especie con un rango de distribución circumtropical y habita en estuarios, manglares, ríos y lagunas costeras. Sus principales amenazas son la sobrepesca y la degradación de su hábitat, pero también son afectados negativamente por el cambio climático y el tráfico ilegal de sus partes. En consecuencia a estas amenazas, *P. pristis* se enfrenta a un grave riesgo de extinción. Panamá forma parte del rango de distribución de las subpoblaciones de *P. pristis* del Pácifico Oriental Tropical (POT) y presenta zonas claves para las poblaciones remanentes en Centroamérica. Sin embargo, la distribución y estado actual de las poblaciones de *P. pristis* en Panamá es incierta, debido a la ausencia de datos que se atribuye a una baja densidad poblacional, lo cual limita la recopilación de información biológica. Mi investigación se enfoca en identificar áreas de ocurrencia de *P. pristis* a lo largo de la costa del POT de Panamá usando un ensayo molecular altamente sensible y preciso (especie-especifico Digital droplet PCR) para la detección y cuantificación de ADN liberado por organismos en forma de tejido, heces, orina, sangre y secreciones corporales excretado en el ambiente (ADN ambiental). Utilizando los datos de ocurrencia por detección de ADN ambiental y parámetros ambientales asociados a la colecta de cada muestra, predeciré el rango de distribución espacial de *P. pristis* en el Pacífico de Panamá aplicando la modelación de la distribución de especies. Los datos generados durante este proyecto nos brindará información relevante para identificar zonas a las cuales dirigir esfuerzos de conservación con el objetivo de asegurar la recuperación de las poblaciones de los peces sierra.

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Explorando la diversidad y distribución de elasmobranquios en el Pacífico de Panamá por medio de ADN ambiental en sedimento marino (sedDNA)

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María Andrea LACAYO-GONZÁLEZ, Helio QUINTERO, and Matthieu LERAY

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Los estudios relacionados a la diversidad de elasmobranquios en el Pacífico de Panamá son limitados y carecen de continuidad temporal, lo que ha generado lagunas de conocimiento dando paso a la incertidumbre actual del estado de estas poblaciones. Los tiburones y rayas son especies migrantes, de madurez reproductiva tardía, amenazadas principalmente por la comercialización de su carne y pérdida de sus hábitats de cría. Algunos hábitats de importancia para este grupo, como manglares, presentan características ambientales que obstaculizan su estudio por medio de métodos convencionales (metodologías visuales); dificultando la elaboración de medidas de conservación en estos sitios clave que son vulnerables a impactos antropogénicos. La secuenciación de ADN ambiental (eDNA metabarcoding) es una técnica biomolecular emergente, que permite la detección de distintas especies de manera no invasiva. En este estudio utilizamos ADN ambiental para metabarcoding (basado en la amplificación del marcador 12S) en muestras de sedimento marino proveniente de estuarios, ríos y manglares para caracterizar la riqueza y distribución de Elasmobranquios en las costas del Pacífico Oriental Tropical de Panamá. Relacionamos la influencia de los factores fisicoquímicos (textura del sedimento, salinidad y temperatura) y ambientales (profundidad, precipitación y cobertura de manglar) sobre la distribución de sus poblaciones. Probamos la aplicación de esta técnica en ecosistemas neotropicales, evaluando si la distribución del tamaño de la partícula influye en la calidad y cantidad de ADN recuperado. Nuestros resultados brindan una perspectiva a la situación actual de las poblaciones de tiburones y rayas. Lo que posibilita la acción informada de las comunidades costeras, además de la creación de herramientas legales que busquen preservar sus hábitats de cría y reduzcan la comercialización de estas especies, con miras a disminuir el impacto antropogénico sobre ellas.

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Patrones de diversidad taxonómica y filogenética en comunidades marinas a lo largo de un gradiente latitudinal

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La tendencia de la diversidad biológica a concentrándose en las regiones tropicales es uno de los patrones más estudiados y reconocidos, aunque su origen sigue siendo uno de los temas más debatidos en ecología. Una hipótesis es que estos patrones resultan de un mayor gradiente en la fuerza de las interacciones competitivas a nivel comunitario, lo que conduce a tasas más altas de especiación ecológica. Sin embargo, todavía hay evidencia limitada sobre las comunidades de invertebrados marinos que constituyen la mayor parte de la diversidad del océano. Las especies estrechamente relacionadas son más similares ecológicamente (la teoría del conservadurismo de nicho), y se pueden detectar patrones de exclusión competitiva en las filogenias comunitarias: si la competencia es importante para estructurar las comunidades, la coexistencia de especies estrechamente relacionadas que desempeñan roles funcionalmente similares deberían dar lugar a una patrón de sobre dispersión filogenética. Estudiamos patrones de composición taxonómica y filogenética de invertebrados marinos y peces de más de 2 mm colectados utilizando Estructuras Autónomas de Monitoreo de Arrecifes (o “ARMS”), en dos hábitats a lo largo de un gradiente latitudinal (de norte a sur: Wachapreague y Fort Pierce en los Estados Unidos, Carrie Bow Cay en Belice y Bahía Almirante en Panamá). Secuenciamos el código de barras (CO1) de un total de 6117 organismos y realizamos una filogenia de las comunidades. Nuestro análisis confirma una alta diversidad en los arrecifes de coral en Bahía Almirante y Carrie Bow Cay en comparación con los arrecifes de ostras en Fort Pierce y Wachapreague. Además, observamos una variación temporal en la diversidad dentro de los arrecifes de ostras, con más variaciones en Wachapreague a lo largo de las diferentes temporadas de colecta. Bahía Almirante y Carrie Bow Cay comparten una composición de especies similar, mientras que Fort Pierce se destacó como el sitio más divergente. Además, utilizamos métricas de diversidad filogenética para probar si el nivel de sobre dispersión filogenética en la comunidad se correlaciona positivamente con la diversidad de especies, lo que sugiere mayor influencia de la competencia en la estructuración de los invertebrados en los trópicos. Nuestros resultados preliminares arrojan luz significativa sobre los procesos de ensamblaje comunitario en invertebrados crípticos y tradicionalmente pasados por alto, que representan la mayor parte de la diversidad de metazoos en el océano.

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Estudio de la abundancia y distribución del sargazo en Playa la Angosta y Nombre de Dios, Colón, Panamá

Presenter: Kevin GOMEZ CORTES

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El sargazo es conocido por su capacidad para formar grandes extensiones flotantes en los océanos tropicales y subtropicales, siendo más común en el Atlántico. Desde 2011, se ha observado un aumento en la cantidad de sargazo que llega a las costas, afectando a numerosos países. En un esfuerzo por comprender mejor este fenómeno, se llevó a cabo un monitoreo durante la temporada lluviosa en Panamá. Este monitoreo se centró en dos playas en el área de Colón: playa La Angosta y playa Nombre de Dios. La primera, una playa turística intervenida por el hombre y la segunda, utilizada principalmente por pescadores locales. Se realizaron mediciones mensuales de la cantidad de sargazo presente en cada playa, encontrando que Nombre de Dios registró mayores cantidades en mayo (14.15 lb por cuadrante), mientras que La Angosta tuvo una presencia menor en el mismo período (3.86 lb). Desde julio hasta noviembre, la presencia de sargazo fue mínima en ambas playas. En diciembre se observó un aumento en la cantidad de sargazo, aunque menor que en mayo. El análisis de los datos utilizando el test de Mann-Whitney reveló que las cantidades de sargazo entre Nombre de Dios y La Angosta fueron similares y no hubo una diferencia significativa entre ellas durante el período estudiado. Además, se investigó si las alturas de marea influían en la cantidad de sargazo, encontrando mediante un análisis de Correlación de Pearson que no había una relación significativa entre estas variables en ninguna de las dos playas durante el período de investigación. Un exceso de sargazo puede perturbar los ecosistemas costeros, impactar la variedad de vida marina y amenazar actividades económicas clave como el turismo y la pesca. Además, esta alga puede ocasionar efectos perjudiciales en la salud humana.

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Respuestas de los tiburones a los cambios climáticos del pasado en el Pacífico panameño: El golfo de Panamá como caso de estudio

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Irene GARCÍA PÉREZ[1,2,3], Erin M. DILLON[1], and Aaron O'DEA[1]

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El cambio global y sus efectos han generado gran incertidumbre respecto al futuro de los arrecifes y los depredadores que los habitan, como los tiburones. Desconocemos la relación entre la salud de los arrecifes y la abundancia de tiburones y cómo podrían cambiar las interacciones ecológicas en función del cambio climático previsto para el futuro. Por ello investigar cómo responden las comunidades de tiburones a la degradación de los arrecifes como consecuencia del estrés climático cobra especial relevancia en zonas como el Pacífico Oriental Tropical, que experimenta una gran variabilidad climática debido al afloramiento estacional y El Niño-Oscilación del Sur (ENOS). Estudiar episodios climáticos ocurridos en el golfo de Panamá como el hiato, el cual se caracterizó por la interrupción anómala del crecimiento de los arrecifes por 2500 años provocada por el ENOS. Por lo tanto el estudio se basa en este periodo de declive de los corales y su relación con los cambios en la abundancia de tiburones. El objetivo es medir la acumulación de dentículos dérmicos depositados en núcleos de matriz arrecifal de los últimos 6000 años en isla Iguana y archipiélago de Las Perlas. Además clasificar los diferentes morfotipos de dentículos para explorar los posibles cambios históricos en la composición funcional de las comunidades de tiburones del Pacífico panameño antes, durante y después del cierre del arrecife. Los resultados proporcionan las líneas bases para conocer la vulnerabilidad y la resistencia de las comunidades de tiburones a lo largo de la historia climática del Pacífico panameño, teniendo implicaciones importantes para la conservación.

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Language Exchanges/Intercambio de idiomas

Presenter: Kathy DARRAGH, Olivia MILLOWAY, Nicole SMITH-GUZMÁN, Carmen SCHLOEDER, Rachel PAGE

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Language exchange classes are a small but significant step in encouraging better connections in our community. Currently, they happen biweekly at four STRI locations with a bilingual teacher helping with both English and Spanish. The classes are open to all members of the STRI community and we hope create a space to help not only improve language skills but also build community and encourage multicultural exchange. Our poster will share the progress of this initiative and advertise upcoming intercambios - please come see us to find out more! Los intercambios son un paso pequeño pero significativo para fomentar mejores conexiones en nuestra comunidad. Actualmente, los intercambios se llevan a cado cada dos semanas y tienen lugar en cuatro estaciones. Durante cada sesión, un profesor bilingüe enseña en inglés y en español. Los cursos son abiertos a toda la comunidad de STRI y crean un ambiente colaborativo para ayudarnos a mejorar nuestras habilidades lingüísticas y crear oportunidades para intercambios de cultura. Nuestro poster compartirá el progreso de esta iniciativa y anunciará los próximos intercambios. ¡Visítenos para obtener más información!

BARRO COLORADO ISLAND 100 YEARS

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June | Junio 20

Abstracts
Resúmenes

June 20 • 10:15 • Gamboa Grand Ballroom

Genetic and species diversity of tropical trees on Barro Colorado Island: Four decades of insights and future directions

Presenter: Andy JONES

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The eco-evolutionary dynamics of tropical tree diversity have been extensively studied on Barro Colorado Island (BCI), providing groundbreaking insights into mechanisms that maintain genetic and species diversity. This research has utilized an array of genetic tools to investigate the effects of evolutionary processes like genetic drift, gene flow, and natural selection on tree populations and communities. Central to these studies is the understanding of how mating systems, dispersal mechanisms, and spatial genetic structure influences genetic diversity within and across species. The application of innovative genetic techniques such has positioned BCI studies at the forefront of tropical tree population genetics. My talk will explore the past four decades of research on BCI, briefly highlighting key discoveries that have shaped our understanding of tropical tree diversity. We will explore how these findings have been influenced by technological advancements in genetic research and the implications for future studies. Looking ahead, I will outline prospective research directions that could bridge existing gaps in our understanding mechanisms that may jointly maintain species and genetic diversity. This includes the potential for integrating genomic tools with long-term ecological data to further elucidate the relationships between genetic variation, environmental factors, and tree fitness. By continuing to leverage the unique research infrastructure on BCI, future studies can enhance our understanding of the responses of tropical forests to global environmental change.

June 20 • 10:30 • Gamboa Grand Ballroom

Novel approaches for measuring biodiversity in tropical forest

Presenter: Daisy DENT

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Monitoring in hyper-diverse tropical ecosystems is challenging due to incomplete baseline biodiversity knowledge, limited research infrastructure, and demanding environmental conditions. Lack of feasible and affordable monitoring approaches can inhibit effective conservation and management strategies. New technologies - such as passive acoustic monitoring (PAM) or environmental DNA (eDNA) - could help to meet this monitoring need. We present data from two case-studies that use PAM in Panama and eDNA in Amazonian Peru to highlight the benefits and limitations of these approaches. In Panama, we found that soundscapes varied significantly among habitat types (including, pasture, secondary forest, plantation and protected forest), but that data must be carefully interpreted using appropriate acoustic indices and, ideally, cross-referenced with complementary data sources. Identification of vertebrate species from eDNA in river water samples from Peru found diverse fish and mammal communities but failed to effectively capture reptile, amphibian and bird assemblages, likely due to taxonomic differences in behaviour and DNA shedding rates. Species level identification of fish was limited by the poor DNA reference libraries for this group. We highlight that limited reference libraries for animal calls and DNA are still a key limitation for broad use of these approaches in the tropics and continued research investment is needed to expand libraries and refine taxonomy.

June 20 • 10:45 • Gamboa Grand Ballroom

Artificial intelligence for natural environments: Automated detection and classification of insects in the rainforest canopy

Presenter: Laurel B. SYMES

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In tropical forests, many animals are hard to see, but few are silent. From large mammals such as primates and elephants, through smaller species such as bats, frogs, birds and insects, many animals produce sounds that can be captured by passive acoustic monitoring (PAM). Rapid advances in machine learning approaches are enhancing our ability to identify individual species within these recordings, monitor and model their distribution and activity, and evaluate their responses to human activities such as poaching, logging, and forest restoration. While automated identification of birds and other key taxa is gaining traction, sounds of insects are often regarded as a noisy confound. However, insect sounds have the potential to convey highly dynamic and granular information about local ecological conditions. As a proof-of-concept to show that acoustics can provide species-level data about insects, we focused on the katydid community of Barro Colorado Island, training a custom machine learning model for 30 katydid species. Approximately three years of data from four recording stations generated nearly a million species-level identifications, which we evaluated for seasonal and spatial patterns in detection rates. We then used the dataset to test the hypothesis that katydid activity varies across the lunar cycle, finding that some species increased calling during nights of bright moonlight, while other species decreased calling. Finally, we discuss emerging projects in the automated identification of insects and other taxa, and the potential applications for basic and applied research.

June 20 • 11:00 • Gamboa Grand Ballroom

Building a science of the sociome

Presenter: Meg CROFOOT

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Meg CROFOOT[1,2,3]

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Building a Science of the Sociome For many animals, success depends not only on the characteristics or decisions of lone individuals, but also on what happens when groups of individuals come together and interact. These collective behaviors and traits can transform the social landscape, giving rise to novel selective pressures that drive the evolution of social complexity. To understand how structured animal societies emerge and function, we need a common framework for quantifying the interactions—from dyad to group to population—that comprise the 'sociome.' Technological innovations—from satellite-based tracking and proximity loggers to drones and computer vision—can generate vast quantities of detailed, noisy data about individual behavior in social contexts, creating new opportunities to map the relationships that structure animal societies. However, our ability to collect data is quickly outstripping our ability to extract biological insight. In this talk, I will discuss the analytical, experimental and technological methods we are developing to harness these tools of our digital age, and illustrate how we are using these approaches to monitor, measure and experimentally manipulate wild animal societies in ecologically and evolutionarily relevant field settings.

June 20 • 11:15 • Gamboa Grand Ballroom

PollenGeo: Palynology moving into the digital world

Presenter: Carlos JARAMILLO

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Carlos JARAMILLO

Smithsonian Tropical Research Institute

The study of pollen and spores started more than a century ago and provides the fundamental basis to understand vegetation changes through time, date sedimentary rocks through biostratigraphy, and model plant evolution among many other applications. Since its origin, palynology has relied on the manual count of pollen and spores using a microscope. This is a process that requires a long time, and years of training, and produces data that is not fully reproducible. The advent of new robotic tools that can digitize complete microscope slides and the fast development of neural network algorithms have provided the timing for Palynology to enter a new era in data generation and analysis. We are developing a training set of neotropical pollen to be used in a neural network that will assist in pollen counts and identification. The developments produced here could be applied to multiple research questions where pollen can be used from paleoecology and paleoclimate, oil, gas, and coal exploration, hydrogeology, and allergology to pollination biology and honey production.

June 20 • 11:30 • Gamboa Grand Ballroom

Characterizing heterogeneity in tropical forest functional diversity using remote sensing

Presenter: Elsa ORDWAY

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Elsa M. ORDWAY[1,2], Gregory P. ASNER[3], David F. R. P. BURSLEM[4], Simon L. LEWIS[5,6], Reuben NILUS[7], Roberta E. MARTIN[3], Michael J. O'BRIEN[8], Oliver L. PHILLIPS[5], Lan QIE[9], Nicholas R. VAUGHN[3], and Paul R. MOORCROFT[2]

1. UCLA. 2. Harvard University. 3. Arizona State University. 4. University of Aberdeen. 5. University of Leeds. 6. University College London. 7. Sabah Forestry Department. 8. Universidad Rey Juan Carlos. 9. University of Lincoln

Although tropical forests differ substantially in form and function, they are often represented as a single biome in global change models, hindering understanding of how different tropical forests will respond to environmental change. The response of the tropical forest biome to environmental change is strongly influenced by forest type. Forest types differ based on functional traits and forest structure, which are readily derived from high resolution airborne remotely sensed data. Whether the spatial resolution of emerging satellite-derived hyperspectral data is sufficient to identify different tropical forest types is unclear. Here, we resample airborne remotely sensed lidar and hyperspectral data to spatial resolutions relevant to satellite remote sensing (30 m) across two sites in Malaysian Borneo, including the ForestGEO Danum Valley plot. Using principal component and cluster analysis, we derive and map seven forest types. We find ecologically relevant variations in forest type that correspond to substantial differences in carbon stock, growth, and mortality rate. We find leaf mass per area and canopy phosphorus are critical traits for distinguishing forest type. Our findings highlight the importance of these parameters for accurately mapping tropical forest types using space borne observations. More broadly, I will provide an overview of new remote sensing technologies that can contribute to our understanding of tropical forests, particularly when integrated with in situ observations, local knowledge, and modeling.

June 20 • 11:45 • Gamboa Grand Ballroom

The impacts of of deforestation and degradation on tropical forest's sensitivity to extremes: An integrated model and remote sensing approach

Presenter: Marcos LONGO

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Marcos LONGO[1], Michael KELLER[2,3], Sassan SAATCHI[3,4], Paul R. MOORCROFT[5], António FERRAZ[3], Xiangtao XU[6], Mauro ASSIS[7], Kevin BOWMAN[3], Ovidiu CSILLIK[3], Eric GORGENS[8], Alexandra KONINGS[9], Erik LARSON[5], Jean OMETTO[7], Elsa ORDWAY[4], Francisca PEREIRA[7], Ekena RANGEL PINAGÉ[10], Luciane SATO[7], Britaldo SOARES FILHO[11], and Lara KUEPPERS[1,12]

1. Lawrence Berkeley National Laboratory. 2. International Institute of Tropical Forestry, USDA Forest Service. 3. Jet Propulsion Laboratory, California Institute of Technology. 4. University of California, Los Angeles. 5. Harvard University. 6. Cornell University. 7. Instituto Nacional de Pesquisas Espaciais. 8. Universidade Federal dos Vales do Jequitinhonha e Mucuri. 9. Stanford University. 10. Wildlife Conservation Society. 11. Universidade Federal de Minas Gerais. 12. University of California, Berkeley

Nearly 40% of the Brazilian Amazon has been deforested or suffered changes in forest structure through degradation (selective logging, fires, and fragmentation). To investigate the important yet uncertain effects of structural changes on forest's sensitivity to droughts, we combined forest structure data from 541 airborne lidar transects (375 ha each) across the Brazilian Amazon with the Ecosystem Demography Model (ED2). We explore the forest response to historical (1981-2019) climate extremes under three forest structure scenarios: (1) observed forest structure from lidar; (2) forest recovery by excluding all future deforestation and degradation; (3) expansion of selective logging and deforestation. Using the observed forest structure, we found that the predicted gross primary productivity (GPP) and evapotranspiration (ET) of the most degraded forests in Eastern and Southern Amazon respond negatively to extremes in vapor pressure deficit (VPD) and downwelling shortwave irradiance (DSWI), indicating high sensitivity to droughts. Across the Brazilian Amazon, high-biomass forest patches showed little or no negative response on GPP and ET to high VPD, whereas low-biomass forest patches negatively responded to higher moisture stress. Consequently, under expanded deforestation and forest degradation, ED2 predicted an expansion in areas where GPP and ET are negatively impacted by hot drought conditions. Our results suggest that the local forest structure of forests is critical for understanding the ecosystem response to climate variability, and that the loss of canopy trees in the Amazon through forest degradation could increase and expand forest vulnerability to droughts.

June 20 • 13:30 • Gamboa Grand Ballroom

The 2024 Gamboa Bioblitz: Results of a rapid participatory biological inventory

Presenter: Steven PATON

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Steven PATON and BioBlitz team

In association with the BCI centennial symposium, STRI is organizing a Bioblitz in Gamboa. A standard Bioblitz is a community science activity to find and ID as many species as possible using smartphone apps. Our enhanced Bioblitz will also include more systematic data collection on some taxonomic groups. Data collection will take place in Gamboa throughout the day and night. Anyone with a smartphone can assist with data collection on June 15, and we welcome people with expertise in species identification help assign taxon names to photos and sound recordings on June 17. This lightning talk will present a brief report on the Bioblitz activities, including statistics on the numbers of observations and species recorded for different taxonomic groups.

June 20 • 13:35 • Gamboa Grand Ballroom

From camera traps to trap-lining: Using motion-detection cameras to monitor foraging behaviour of individual butterflies

Presenter: Denise Dalbosco DELL'AGLIO

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Denise Dalbosco DELL'AGLIO[1,2], Owen W MCMILLAN[1], and Stephen MONTGOMERY[2]

1. Smithsonian Tropical Research Institute. 2. University of Bristol

The activity of many animals follows recurrent patterns and foraging is one of the most important processes in their daily activity. Determining movement in the search for resources and understanding temporal and spatial patterns in foraging has therefore long been central in behavioural ecology. However, identifying and monitoring animal movements is often challenging. In this study we assess the use of camera traps to track a very specific and small-scale interactions focused on the foraging behaviour of *Heliconiini* butterflies. Data on floral visitation was recorded using marked individuals of three pollen-feeding species of *Heliconius* (*H. erato, H. melpomene* and *H. sara*), and two closely related, non-pollen feeding species (*Dryas iulia* and *Dryadula phaetusa*) in a large outdoor insectary. We demonstrate that camera traps efficiently capture individual flower visitation over multiple times and locations and use our experiments to describe some features of their spatial and temporal foraging patterns. *Heliconiini* butterflies showed higher activity in the morning with strong temporal niche overlap. Differences in foraging activity between males and females was observed with females foraging earlier than males, mirroring published field studies. Some flowers were more explored than others, which may be explained by butterflies foraging simultaneously affecting each other's flower choices. Feeding was grouped in short periods of intense visits to the same flower, which we refer to as feeding bouts. Heliconius also consistently visits the same flower, while non-Heliconius visited a greater number of flowers per day and their feeding bouts were shorter compared with Heliconius. This is consistent with *Heliconius* having more stable long-term spatial memory and foraging preferences than outgroup genera. More broadly, our study demonstrates that camera traps can provide a powerful tool to gather information about foraging behaviour in small insects such as butterflies.

June 20 • 13:40 • Gamboa Grand Ballroom

Linking seed dispersers' movement to seed dispersal patterns: Insights from movement ecology

Presenter: Noelle G. BECKMAN

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Binod BORAH[1], Margaret CROFOOT[2,3], Roland KAYS[4,5], and Noelle G. BECKMAN[1]

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Frugivore movement is crucial for animal-mediated seed dispersal. Frugivore physiology, motion capacities, navigation capabilities, and biotic interactions shape the movement process, influencing seed removal and deposition patterns. Using the 'movement ecology paradigm,' we can analyze the drivers of frugivore movement, categorize it into canonical activity modes, and examine its potential impacts on seed dispersal effectiveness. We used high-resolution telemetry data of spider monkeys and LiDAR derived environmental data from Barro Colorado Island; classified spider monkeys' movement into their activity modes; estimated their selection for different habitat conditions; and integrated them all into a seed dispersal model. Based on empirically informed habitat selection and distribution of canonical activity modes, we simulated disperser movement and tracked where and how far they deposit seeds. Spider monkeys selected habitats with taller canopy and terrain ruggedness and mostly encamped and deposited more seeds in these habitats compared to spider monkeys with no habitat affinities. Spider monkeys also avoided treefall gaps and deposited fewer seeds there compared to monkeys that did not avoid gaps. Spider monkeys with habitat preferences generated shorter seed dispersal distances than spider monkeys with no habitat preferences. In summary, external factors, like habitat conditions, can drive seed dispersers' habitat selection, activities, and movement which in turn leaves distinct signatures on seed dispersal patterns. Our framework integrates movement drivers, frugivore activities, and seed dispersal services, suggesting future directions for research using advances in animal movement studies.

June 20 • 13:50 • Gamboa Grand Ballroom

Using Internet of Things (IoT) networks to track animals in Peru and Panamá

Presenter: Roland KAYS

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Miniaturizing GPS technology has revolutionized our ability to track animal movement, but we still have the challenge of getting the data back from free-ranging animals. Satellite and cellphone networks are expensive and power hungry, requiring larger batteries, and thus limiting what species can be tracked. Internet of Things (IoT) networks provide a new low-power communication option that might enable smaller, more efficient tags. We tested the utility of the Sigfox IoT network for tracking animals in Amazonian Peru, Coastal Peru, and in Panama City, Panamá. We tracked 6 species of birds and 6 species of mammals with varying tag types and varying levels of success. The antenna we mounted on a tower in the Amazon had ~10km range to the forest floor but ~60km to a soaring bird. In Panama City and along the Peruvian coast we relied on commercially provided networks, which had spotty coverage, but tags continued to collect GPS points when out of range and could send them all when the animal returned to coverage. IoT network coverage is still limited in the Americas but our results suggest it could be a useful solution for animal tracking through a combination of existing infrastructure and researcher's supplementing coverage around key areas with additional antennas.

June 20 • 14:00 • Gamboa Grand Ballroom

Quantifying landscape-level tropical forest dynamics on Barro Colorado Island, Panama at fine temporal, spatial, and potentially taxonomic resolution using repeat drone photogrammetry

Presenter: Helene C. MULLER-LANDAU

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Helene C. MULLER-LANDAU[1], K. C. CUSHMAN[2], Vicente VASQUEZ[1], Raquel F. ARAUJO[1], Mia MITCHELL[1], Milton GARCIA[1], Pablo RAMOS[1], Paulino VILLAREAL[1], and Melvin HERNANDEZ[1]

1. Smithsonian Tropical Research Institute. 2. Oak Ridge National Laboratory.

Tropical tree mortality rates vary widely over time within sites in relation to climate cycles and long-term change, and serve as a major control over tropical forest carbon stocks globally. However, we still have a relatively poor understanding of their drives, in part because rates are low and traditional field methods are labor-intensive. We used repeat drone photogrammetry to quantify fine scale temporal and spatial variation in canopy tree mortality and branchfall over large areas and evaluate their relationships with temporal climate variation and spatial variation in environmental factors. Our drone imagery dataset spanned 9.5 years of monthly data for a 50-ha plot (since 2014, 5 cm resolution), and 5 years of annual data for all 1500 ha of Barro Colorado Island, Panama (since 2018, 20 cm resolution). Canopy tree mortality and branchfall rates exhibited strong variation with space, time, and their interactions. Spatially, mortality rates varied with topography, soil type, and forest age. Temporally, disturbance rates were higher during months with more extreme storms. Canopy disturbances were somewhat more likely in areas close to prior year disturbances. We also produced ground-validated crown maps linking crowns visible in the imagery to tagged trees of known species identity. We combined these maps with automated crown segmentation to track crowns of individual trees of known species identity over time, and thereby quantify phenological signatures for canopy tree species. We are exploring the potential to classify canopy tree and liana taxa or groups from these phenological signatures, or alternatively from hyperspectral reflectance or 3D structure, to enable automated taxon-specific mapping over large areas. Our results to date demonstrate the utility of repeat drone photogrammetry to quantify spatial and temporal variation in tree mortality in diverse tropical forests at fine temporal resolution over large spatial scales, and thereby investigate the drivers of tree mortality patterns in a changing environment. Our work in progress has the potential to add high taxonomic resolution as well, which would enable major advances in our understanding of interspecific variation in climate responses of tropical trees and lianas, and in our ability to project the future of these diverse ecosystems under global anthropogenic change.

June 20 • 14:10 • Gamboa Grand Ballroom

Tracking individual tree crowns across time using widely available AI models and high resolution drone imagery

Presenter: Vicente VASQUEZ

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Smithsonian Tropical Research Institute

The availability of drone imagery presents a unique opportunity to unveil the intricate dynamics of tropical forest ecosystems. High-resolution time series enable the observation of phenological events in the forest canopy including leaf-shedding, re-leafing, flowering, and fruiting. To fully utilize the data and track individual tree crowns over time, we confront the challenge of attributing pixels to specific plants. While manual delineation is feasible and has been implemented here as a validated starting point, its laborious nature renders it impractical for large-scale and multi-temporal analysis. Herein lies the motivation for leveraging widely available AI models to automate the segmentation of individual trees. In this methods-focused talk, we describe a robust workflow to track individual tree crowns and extract ecologically significant features across time. We used drone-acquired imagery to monitor the forest canopy of the Barro Colorado Island 50-ha plot on monthly to weekly scales from 2018 to 2024, and generate a time series of high-resolution (4.5-cm) orthomosaic images. During three mapping campaigns, expert field technicians meticulously mapped crowns visible in the imagery,thereby associating canopy geometries with tree tag numbers and species IDs recorded in ground-based tree censuses. They also recorded crown damage, illumination, and liana cover. We present a fully automated workflow to process time series of drone imagery including spatially aligning imagery for different dates, and segmenting individual tree crowns. The orthomosaics are corrected for global and local shifts using color co-registration from the Arosics Python package. The ground-validated tree crown maps are improved by refining the edges using the SegmentAnything (SAM) AI model. Finally, imagery in the rest of the time series is segmented, starting with information from the ground-validated map and proceeding to adjacent dates. These methods enabled the extraction of multi-temporal features for individual trees, including changes in crown size related to mortality, damage, and growth, as well as changes in color and texture that reflect phenological events. These features thus provide important data on forest dynamics and phenology. By enabling forest monitoring over larger areas and higher temporal resolution, they offer the potential for deeper insights into the intricate dynamics of tropical forests.

June 20 • 14:20 • Gamboa Grand Ballroom

Giant trees and lightning: Expected deaths, unexpected benefits, and new directions

Presenter: Evan M. GORA

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Evan M. GORA[1,2], Helene C. MULLER-LANDAU[2], Stephen P. YANOVIAK[2,5], K. C. CUSHMAN[2,3], Vanessa E. RUBIO[1], Jeannine H. RICHARDS[4,5,6], Phillip M. BITZER[7], Jeffery C. BURCHFIELD[8], Cesar GUTIERREZ[2], Pablo NARVÁEZ[2], and Adriane ESQUIVEL-MUELBERT[9]

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The largest 1% of trees in tropical forests (hereafter giant trees) contribute nearly 50% of aboveground biomass stocks and fluxes, and they play disproportionate roles in population dynamics and local patterns of diversity. Consequently, giant tree mortality strongly shapes forest composition, structure, and function. However, we know remarkably little about where, when, and why giant trees die because forest plots are too small to capture patterns of their mortality. We have deployed a series of sensors over the past decade to begin unraveling the effects of lightning strikes and other drivers of giant tree mortality across BCI and the broader region. This began with a local lightning location array on BCI in 2014 (<500 ha), and has scaled up to regional lightning location (800,000 ha) and subregional, high-frequency drone monitoring (1,500 ha). Here we present the development of these remote sensing systems over the past decade along with key findings. We show that lighting is the primary cause of mortality for giant trees on BCI because it non-randomly strikes the tallest trees with the broadest crowns. However, not all trees die when struck by lightning, and certain tree taxa counterintuitively benefit from being struck. For example, Diperyx oleifera survives lightning strikes with negligible damage while their neighboring competitors and the lianas infesting their crowns die, thereby the ability to survive lightning increases their fecundity by as much as 14-fold. We are now embarking on a new stage of this research as part of the “Gigante” project in which we follow the fates of all giant canopy trees across BCI using monthly drone monitoring paired with detailed tree forensics on the ground.

June 20 • 14:30 • Gamboa Grand Ballroom

Innovating ambition to action: Technological implementation, data integration and multilateralism for the Global Biodiversity Framework

Presenter: Peter R. HOULIHAN

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Peter R. HOULIHAN[1,2,3]

1. XPRIZE Foundation. 2. UCLA, Center for Tropical Research. 3. Johns Hopkins University, Environmental Science & Policy

The Global Biodiversity Framework adopted by the United Nations Convention on Biological Diversity sets ambitious targets to combat the urgent planetary crisis of biodiversity loss. Achieving these goals within this decade necessitates a paradigm shift in how biodiversity monitoring is conducted, especially for the most biodiverse terrestrial ecosystems: tropical rainforests. In 2019, XPRIZE Rainforest was launched to accelerate the co-design, co-creation, implementation, and scaling of innovative solutions that can document and monitor tropical rainforests in near real-time, enabling local stakeholders with the tools and data collection means necessary to effectively manage vast areas including parks and Indigenous territories, establish new protected areas, and measure the efficacy of reforestation efforts in restoring biodiversity and ecosystem function and value. Throughout the text of the Global Biodiversity Framework, the important role of applying technology and innovation is stressed for countries to accomplish their State Biodiversity Strategy and Action Plans. Following the Finals field testing and evaluation of XPRIZE Rainforest technologies in the Brazilian Amazon in July 2024, the first phase of implementation of successful solutions will be initiated with the country of Brazil, working at state and federal levels and with Indigenous communities. These innovations include advanced sensor networks, drone technologies, environmental DNA, AI-driven species identification, and data integration platforms that generate and report comprehensive ecological insights within 48-hours of surveying the biodiversity of a rainforest. The integration of these technologies presents a unique and essential opportunity to bridge the gap from ambition to action by providing the necessary data and insights to inform policy and conservation strategies at scale. Following the launch of piloting this country-wide approach, implementation will be expanded globally in partnership with Indigenous communities and countries to monitor, manage and protect tropical rainforests and other terrestrial environments of high biodiversity, by 2030, to collaboratively harness the innovative tools, collective knowledge, and ambition required to safeguard the future of life on Earth.

June 20 • 14:40 • Gamboa Grand Ballroom

GEO-TREES: A global forest biomass reference system

Presenter: Stuart DAVIES

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Stuart DAVIES, Jerome CHAVE, IRIS DION, Oliver PHILLIPS, Camille PIPONIOT-LAROCHE, and Klaus SCIPAL

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Land vegetation is a large carbon store and represents opportunities to sequester additional carbon. While many Earth Observation missions aim to estimate forest carbon from space, their calibration and validation is critical. Ultimately trust in biomass maps requires accurate ground data. Supporting ground measurements and the people who make them is thus mission-critical for mapping and tracking Earth's forest carbon. Building on decades of work from the global research community with a strong representation of partners from the Global South, the GEO-TREES initiative aims to fund high quality ground data from a global network of long-term forest inventories, and to make these data open access. Biomass Reference Measurement sites (BRM) are in situ forest measurement sites with a common standard for high-quality data acquisition, transparent measurement protocols, long-term monitoring, and measurements traceable to SI units. GEO-TREES will be established through collaboration with existing international networks of high-quality forest plots that use standard forest monitoring protocols. The Forest Biomass Reference System will be centered on 100 core BRM sites representing forests around the world, with strong priority placed on the tropics. Core sites will consist of long-term intensive measurements of forest biomass. An additional 200 supplementary BRM sites will be used to ensure full representation of the main environmental and anthropogenic dimensions over which forests occur globally. Supplementary sites will involve less intensive biomass sampling, but will provide a strategy for gap-filling under-represented areas. The raw biomass data collected by the GEO-TREES project will be made publicly accessible through the GEO-TREES web portal. To deliver these high-quality data over a sustained period in dozens of countries requires skilled teams hosted by institutional partners. The labor and skill demanded for the groundwork are high, and conditions of work are often insecure and difficult. It follows that for in situ data to be shared openly GEO-TREES partners will be fairly and systematically funded with adequate provision of training and career development. The intellectual property of the primary stem and species data remain with the principal investigators of each site.

June 20 • 14:50 • Gamboa Grand Ballroom

PANGEA: A scoping study for a NASA tropical forest terrestrial ecology campaign

Presenter: Elsa ORDWAY

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Elsa ORDWAY, Isaac AGUILAR, Ane ALENCAR, Adia BEY, Dana CHADWICK, Lola FATOYINBO, Yanlei FENG, António FERRAZ, Jose FUENTES, Peter GRIFFITH, Michael KELLER, Lydie-Stella KOUTIKA, Yue LI, Junjie LIU, Marcos LONGO, Ian MCCUBBIN, Charles MILLER, Helene MULLER-LANDAU, Félicien MEUNIER, Patrick NAMULISA, Robinson NEGRON-JUAREZ, Teodyl NKUINTCHUA, Matheus NUNES, Le Bienfaiteur SAGANG, Maria SANTOS, Fabian SCHNEIDER, Bonaventure SONKÉ, Hannah STOUTER, César TERRER, Marius VON ESSEN, Michelle WONG, Sarah WORDEN, and Xiangming XIAO

The tropics are experiencing dramatic changes as a result of climate change and land-use change. Shifts in carbon flux dynamics, water cycling, and species composition are resulting in feedbacks with globally important consequences for biodiversity, climate change, and agricultural production. Yet, we also know that tropical forests are not uniform. Their species diversity, climate, soils, and human impact vary enormously from the Americas to Africa to Asia. As a result, tropical ecosystems are already showing evidence of varying responses to climate and land-use change. However, these differences remain highly uncertain and poorly understood. PANGEA is a NASA funded effort to scope a 6- to 9-year multi-scale campaign in the tropics focused on improving understanding of the heterogeneous responses to climate change, with broad research focus on biodiversity, biogeochemical cycling, and agriculture. We have one year to work with the international research and user communities to outline a possible campaign in the tropics. At the end of 2024, we will submit a white paper to NASA detailing our proposal. If selected, the campaign would support coordinated fieldwork and airborne remote sensing data collection that will inform our use of satellite remote sensing and modeling to better understand change dynamics in the tropics. Although there is no guarantee that NASA will support the recommended project, this is a once-in-a-decade opportunity to assemble multi-disciplinary research communities to align efforts and outline a focused campaign.

June 20 • 16:05 • Gamboa Grand Ballroom

BCI as a hub for globally distributed experiments

Presenter: Jim DALLING

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How do we continue to build on the expertise and accumulated scientific knowledge of BCI while simultaneously expanding our inference space about tropical ecology? What role can BCI play in supporting inclusiveness in science not just in Panama but across the tropics? One solution is to use the infrastructure of BCI as a hub for the development of regionally or globally distributed experiments which share a common protocol collectively designed by teams of researchers from diverse sites and with diverse skills. I envision a call for proposals for protocols that are developed, refined and adapted on BCI. Projects could be hierarchical, with some activities restricted to resource-rich sites, but a primary focus will be on determining what works in low-infrastructure sites, increasing opportunities for broad participation across the tropics. At the same time, project coordinators will encourage individual teams to explore opportunities to build site-specific activities that complement the core activities. I will highlight two distributed studies: the collection of soils data standardized across ten ForestGeo sites carried out 20 years ago, and a more recent wood decomposition experiment replicated at 300 sites.

June 20 • 16:10 • Gamboa Grand Ballroom

Rainforest Snapshot

Presenter: Roland KAYS

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The large size of many birds and mammals allows them to play big ecological roles in rainforests but also makes them vulnerable to habitat loss and poaching. However, data on their populations is limited and scattered. **We propose a super-collaborative annual camera trap survey** of wildlife across Panama, Costa Rica, and eventually more tropical countries. This project would build off the sustainable “Snapshot model” proven through five years of monitoring across the USA (plus 3 in Europe and 1 in Japan). In Snapshot surveys, a network of scientists 1) set arrays of their own camera traps in local forests for two months following a standard protocol, 2) upload their data to a common database, and 3) publish the data as a paper with all collaborators as coauthors. The model is sustainable because we ask relatively little of collaborators and they get ‘payment’ through a publication, and a collaboration network. The network can be strengthened with loaner camera trap kits for underserved communities, analytical workshops, student research symposia, and by extracting even more information from the images with AI. By providing a sustainable annual snapshot of mammal populations across large scales, we think Snapshot Rainforest can transform tropical forest science.

June 20 • 16:15 • Gamboa Grand Ballroom

BIO-Acoustics

Presenter: Laurel SYMES

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How do we continue to build on the expertise and accumulated scientific knowledge of BCI while simultaneously expanding our inference space about tropical ecology? What role can BCI play in supporting inclusiveness in science not just in Panama but across the tropics? One solution is to use the infrastructure of BCI as a hub for the development of regionally or globally distributed experiments which share a common protocol collectively designed by teams of researchers from diverse sites and with diverse skills. I envision a call for proposals for protocols that are developed, refined and adapted on BCI. Projects could be hierarchical, with some activities restricted to resource-rich sites, but a primary focus will be on determining what works in low-infrastructure sites, increasing opportunities for broad participation across the tropics. At the same time, project coordinators will encourage individual teams to explore opportunities to build site-specific activities that complement the core activities. I will highlight two distributed studies: the collection of soils data standardized across ten ForestGeo sites carried out 20 years ago, and a more recent wood decomposition experiment replicated at 300 sites.

June 20 • 16:20 • Gamboa Grand Ballroom

FOREST-UP: Forest understanding and conservation through plant metabolites

Presenter: María-José ENDARA

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Tropical rainforests harbor a large fraction of the world's diversity of vascular plants. Plants harbor a vast array of chemicals through which evolutionary and ecological processes shape plant biodiversity, and through which plant biodiversity, in turn, influences ecosystem processes. Despite this, plant chemistry remains largely absent from ecological research. In this project, we seek to leverage recent advances in the fields of metabolomics to perform a survey of tree chemical diversity across the Ecuadorian Amazon. Using a network of 80 one-hectare plots that covers most habitats in the Amazon, including terra firme, white sand, varzea and igapó forests, and spans a gradient in precipitation and temperature, we propose to 1) characterize the metabolite diversity of nearly 1/3 of Ecuadorian's Amazon tree species; 2) study the evolutionary history of target plant lineages to understand the role of plant defense chemistry in the diversification of tropical forests; 3) spatially map chemical diversity as a tool for biological conservation. This unprecedented survey will allow us to make generalizations regarding some of the most pressing questions in biodiversity science, such as how diversity is distributed over space, how it changes over time and how it responds to land use and climate change.

June 20 • 16:25 • Gamboa Grand Ballroom

A long-term monitoring programme for rainforest insects

Presenter: Owen LEWIS

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Owen LEWIS

University of Oxford

There is growing concern that populations of many insect species are declining, with potentially far-reaching ecological consequences. Insects are a key component in rainforest food webs, helping to structure plant diversity and mitigate the effects of climate change, as well as mediating critical ecosystem services (such as pollination) and disservices (such as vectoring diseases). Their short generation times and the fact that they operate close to their critical thermal limits also mean that tropical insects are expected to be particularly sensitive to climate change. Long-term data quantifying the dynamics of tropical insect populations are extremely rare, but for the last 15 years, the STRI/ForestGEO Arthropod Initiative has successfully monitored the dynamics of 1,702 species representing 23 insect taxa on Barro Colorado Island, Panama. We propose to extend and develop this programme, capitalising on new technologies including cost-effective DNA barcoding and metabarcoding, AI-enabled camera-traps, and bioacoustics. This will generate a unique, long-term dataset, closely integrated with data for other taxa including ForestGEO plant data. This resource will be transformative in allowing ecologists to understand the temporal dynamics of the rainforest insect community and its ecological drivers, as well as the consequences for other components of the rainforest food web.

June 20 • 16:30 • Gamboa Grand Ballroom

Deep Dive: a global exploration of tropical soil chemistry and food webs

Presenter: Jane LUCAS

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Soils are fundamental to tropical ecosystems, hosting vast biodiversity and storing the majority of carbon. Despite this, our understanding of tropical soil communities and their functions remains limited. Indeed, belowground communities (i.e., microbes and invertebrates) drive global nutrient cycles and regulate tropical forest functions, yet they are largely uncharacterized; we understand less about these communities than any other aspect of tropical ecosystems. Global studies on tropical forest dynamics rarely detect strong correlations between soil characteristics and aboveground communities. This discrepancy is likely due to inadequate soil data, not the insignificance of soils. We are proposing the first comprehensive assessment of soil chemistry, physical characteristics, and food webs—including bacteria, fungi, and invertebrates—across thousands of tropical forest plots. This initiative involves (1) thorough chemical and physical soil assessments, with an emphasis on soil carbon across multiple depths, (2) eDNA and metagenomic techniques to characterize belowground food webs and functions, and (3) repeated sampling to capture temporal and spatial variability from local to global scales. This campaign will catalyze numerous research projects and reveal the hidden biodiversity and functions of the belowground world, which is critical for predicting the future of tropical forests and their role in the carbon cycle.

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The EvoGEO (EVOlutionary dynamics Global Earth Observatory) initiative

Presenter: Andy JONES

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EvoGEO aims to bridge the gap in our understanding of genetic variation and its role in the eco-evolutionary dynamics of tropical forests. We propose a data collection campaign will conduct a comprehensive community-wide analysis of genetic variation for hundreds of coexisting tropical woody plant species on Barro Colorado Island. By integrating 40+ years of demographic and phenotypic data with novel genomic data, EvoGEO will elucidate the genetic underpinnings of individual, population, and community responses to environmental change. Key data collection activities include generating high quality reference genomes and genotyping individually tagged trees using advanced genomic tools, reconstructing historical demography of species, monitoring allele frequency changes across censuses, and integrating these data with modern coexistence theory. This will enable us to differentiate between random and selective forces acting on individuals and directly observe eco-evolutionary dynamics. EvoGEO's transformative potential lies in its ability to provide unprecedented insights into the maintenance of species and genetic diversity, relationships between genotypes, phenotypes, microbiomes, metabolomes, and quantify levels of standing adaptive genetic variation. This initiative will serve as a model for expanding similar studies across the ForestGEO network, offering a global comparative context to advance our understanding of tropical forest science.

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Species-specific monitoring of all woody plants on all BCI using drones, hyperspectral imaging, laser scanning, and AI

Presenter: Helene C. MULLER-LANDAU

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The high plant diversity of tropical forests offers the potential for high resilience to anthropogenic global change because species vary widely in their responses. However, we need orders of magnitude more species-specific data on woody plant performance at high temporal resolution to quantify this critical interspecific variation. We will take advantage of technological advances in drones, laser scanning, hyperspectral imaging, and AI to census woody plants across all BCI (1540 ha) on weekly to annual intervals. Weekly drone flights with lidar and hyperspectral cameras will quantify growth, mortality, phenology, and reproduction of canopy trees and lianas in relation to environmental conditions. Annual understory laser scanning and spectral data collection will census all seedlings and saplings. We will develop and apply AI tools for automatic species classification from 3D structure and multitemporal hyperspectral imaging, so that all data will be species-specific. This project will provide huge volumes of new data on plant performance across life stages at high temporal resolution, enabling quantification of how individual woody plant species respond to storms, droughts, climate variation, and more, as well as contributing highly useful for modelling and remote sensing calibration and validation. It will also develop broadly useful methods tools for forest monitoring and species classification.

BARRO COLORADO ISLAND 100 YEARS

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Posters

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Next-gen insect monitoring: AMI systems and insect monitoring on Barro Colorado Island

Presenter: Adolfo ALBA POLANCO

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Due to the high levels of insect diversity, especially in the tropics, monitoring schemes for arthropods are far between. Despite this challenge, the Arthropod Monitoring Program on Barro Colorado Island has been studying the local insect community for the last 15 years, through the implementation of focal groups and the continuous refinement of the taxonomy. Naturally the monitoring is limited to focusing on certain families due to the high abundance of insects attracted to protocols such as light traps used for the study of night flighting insects. New advancements on the field of image sensors and machine learning are opening the opportunity of combining the concept of camara traps and image detection to study and monitor insect communities. The AMI Systems is one of these new methods of Insect monitoring. This device will be used to study night flight lepidopterans allowing: the automatic identification of insect species, the study of insect activity though the night and thought the year and allow for a transition from traditional night flying insect monitoring to next gen methods. That's why we are testing the feasibility of these new protocols on Barro Colorado Island, comparing 10 AMI Systems with the 10 sites use in the STRI's Arthropod Program, were we are going to compare a 1 years round of autonomous monitoring with the 4 sampling periods of the monitoring to see the efficacy on species detection and species overlap between methods.

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Next steps in insect monitoring: the prospects of metabarcoding

Presenter: Eduardo NAVARRO-VALENCIA

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The last 15 years the Arthropod Monitoring program of BCI has study the insects of Barro Colorado Island in the 50ha plot of the ForestGeo Program using a series of classical entomological protocols with the advantages of DNA Barcoding for the identification and cataloging of the species on the Island. The insect communities for the focal groups of the monitoring have been rather well surveyed, using the advantage of a well study community of insects in the tropics, we tested the feasibility of using metabarcoding through bulk insect sample modifying 7 common insect sampling protocols. We tested the 7 protocols in 25 sites inside the 20x20m subplots of the 50ha plot, once in the dry season and once in wet season. In this poster we are going to showcase preliminary data concerning the results of a common flight intercept trap, the Malaise trap, and a common ground trap, the Pitfall trap.

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Digitization and morphological analysis of modern pollen samples of the subfamily Asteroideae (Asteraceae) from northern South America.

Presenter: Thiago WOOD PIRES

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The study of pollen grains has greatly contributed to understanding the evolutionary patterns of the Neotropics vegetation. Pollen morphology can vary in several aspects according to plant family and genus, offering a tool for taxonomic and evolutionary inferences. The family Asteraceae is one of the most diverse families of flowering plants in the world with an estimate of 25.000 - 35.000 species divided in 16 subfamilies and 51 tribes, with a cosmopolitan distribution. The subfamily Asteroideae is the most nested within the evolutionary history of the family and also the largest in number of species, segregated along 21 tribes. Asteroideae pollen is regarded as morphologically homogeneous across its tribes according to conventional microscopy and palynology techniques, which has remained the same for over a century. This may limit the comprehension of taxonomical relationships and the assignment of fossil morphotypes or extant pollen to a specific tribe or genus in the subfamily. This project aims for digitizing and analyzing the Asteroideae specimens in the Smithsonian Tropical Research Institute palynological collection through the use of new high-resolution microscopy techniques. The results provided will allow more accurate taxonomic identification for the different tribes and genus of the subfamily, help in resolving the fossil records and improve the use of pollen characters for ecological and evolutionary concerns within the family.

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Digitization of palynological samples of Bombacaceae family from the Graham's collection

Presenter: Natalia OVALLE ROMERO

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A collection of pollen and spores from Barro Colorado Island (BCI) is available in the classical microscopy photographic format, where diagnostic traits are visible, but there is not enough information for an automated recognition process. The digitization of Graham's collection and other modern pollen collections is an ongoing process, which includes slides of specimens from BCI that are in a decaying state. Pollen grain photos are taken using three techniques: Transmission light techniques—Brightfield (BF) and Differential Interference Contrast (DIC)—and Confocal microscopy. The result enables a comprehensive digital image analysis of the whole pollen grain for palynologists. The Bombacaceae family is represented by 1180 photos of 32 species across 7 genera in BF and DIC techniques in this digital collection, with the possibility of expansion in the near future from other collections. The ornamentation disposition of their pollen grains appears easier to measure, yet it varies significantly between species being reticulate the most important one. Through detailed morphological measurements of the reticulate ornamentation, it should be possible to discriminate pollen grains at the species level.

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Building the basis for automated species identification of tropical plants from hyperspectral and laser scanning data

Presenter: Juan C. OSORIO–OSPINA

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1. Smithsonian Tropical Research Institute. 2. NASA Jet Propulsion Laboratory. 3. University of Maryland, College Park.

Tropical forests account for a majority of terrestrial carbon stocks and biodiversity, and it is thus critical to understand how they are being affected by climate change. Their plant biodiversity offers the potential for resilience to anthropogenic global change because species vary in their responses to environmental variation. However, this very diversity presents a challenge to our ability to understand tropical forest function today and to predict how it will change, as it means interspecific variation is critical. We currently lack the abundant, species-specific data needed to quantify this variation. Technological advances in hyperspectral imaging, laser scanning, and artificial intelligence offer the potential for automated species identification of plants using remote sensing. However, to realize this potential we need to collect high-quality training data and analyze it to develop appropriate algorithms and determine which combinations of data are most useful for species identification. In this path-finding study, we strive to build the basis for automated species identification of woody plants in diverse tropical forests. We are currently collecting high spectral resolution data on reflectance of flowers and fruits of tree and liana species on Barro Colorado Island, complementing previously collected data on leaf and whole crown reflectance. We are also developing protocols for measuring 3D structure of plant organs and seedlings, with the aim of evaluating the potential for automatic species recognition from ground-based and drone-based laser scanning data. These datasets will allow us to quantify within species consistency and among species differentiation in hyperspectral reflectance and 3D structure of different plant parts and whole plants, evaluate the ability to distinguish taxa, and identify the most promising approaches for automated species identification.

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Quantifying carbon fluxes from tree mortality and damage through the integration of drone photogrammetry and ground field surveys

Presenter: Luisa F. GÓMEZ-CORREA

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Luisa F. GÓMEZ-CORREA[1], Daniel ZULETA[2], Vicente VÁSQUEZ[1], Salomón AGUILAR[1], Gabriel ARELLANO[3,4], Stuart J. DAVIES[2], Milton GARCÍA[1], David MITRE[1], Rolando PÉREZ[1], Pablo RAMOS[1], and Helene C.MULLER-LANDAU[1]

1. Smithsonian Tropical Research Institute. 2. Forest Global Earth Observatory. 3. Ecology and Evolutionary Biology, University of Michigan. 4. Oikobit LLC.

Tree mortality and damage play important roles in determining aboveground biomass fluxes; however, both are still poorly understood, especially due to their high spatial and temporal variability. Tree mortality and damage could be assessed through ground field surveys, which provide fine temporal resolution data but are highly time-consuming and cover limited areas. On the other hand, drone photogrammetry allows the detection of canopy disturbances repeatedly over time in commonly larger forest areas than ground surveys. Integrating ground surveys and canopy disturbance data will allow us to comprehensively assess tree mortality and damage and quantify their associated biomass losses at varying spatial and temporal scales. In this study, we compare the biomass losses from tree mortality and damage from ground field surveys of 6,897 individuals at the BCI 50-ha permanent plot from 2021 to 2022 and the percentage of crown area affected by canopy disturbances detected with drone photogrammetry across the same period. We compared the biomass losses and percentage of canopy disturbed using different quadrant sizes and tree diameter at breast height (DBH) thresholds. We found low agreement between the number of quadrats classified as damaged and undamaged within ground surveys and drone photogrammetry, being more similar when only trees with DBH ≥ 40 cm are included. Preliminarily, the low agreement among approaches could be due to their inherent difficulty in detecting damages across the forest strata (e.g., understory vs. canopy layer), timing differences among assessments, and tree deciduousness causing false damage detection in drone photogrammetry. We will discuss methodological ways to account for the differences between both approaches and propose models to estimate biomass losses given the forest volume disturbed detected with drone photogrammetry.

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Quantifying patterns of lightning-caused canopy disturbances in the Barro Colorado Island with the integration of drone imagery and field surveys

Presenter: Evan M. GORA

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1. Smithsonian Tropical Research Institute. 2. Department of Forest Engineering, University of Brasília. 3. Cary Institute of Ecosystem Studies. 4. Future Carbon Group

The dynamics of gaps in tropical forests contribute to the maintenance of diversity and forest carbon dynamics. Lightning strikes are a major agent of tree mortality and gap formation in Panama forests. However, we lack information about the quantification of lighting-caused canopy disturbances by remote sensing and their spatiotemporal patterns. Our objectives were to quantify patterns of lightning-caused canopy disturbances, specifically their timing after the strike date and their spatial distribution in relation to the strike site, and to evaluate the utility of drone imagery in quantifying lightning-caused disturbances, by comparing drone-detected patterns of lightning-associated canopy disturbances with ground-assessed patterns of tree damage, tree mortality, and biomass mortality. The canopy disturbances identified from monthly drone imagery and field data were collected in the 50ha plot of the Barro Colorado Island from Oct 2, 2014 to Nov 28, 2019 and from Sept 21, 2015 to Oct 5, 2019, respectively. We found that the average time for the first canopy disturbance to appear was 222 days. The average time to the last canopy disturbance was 393 days. Canopy disturbance area was concentrated close to the rooting point of the directly struck tree. Specifically, 43% of the total lightning-associated canopy disturbance area was within 10 m of this rooting point, whereas only 3% of canopy disturbance area was 30-40m from this rooting point, on average. Drone-detected canopy disturbance area imagery was a good predictor of variation in field-estimated biomass turnover, number of dead trees, and total disturbed area among lightning strike sites. Drone estimates of canopy disturbance area were approximately half that of disturbance area estimated using ground-based measurements of tree location, canopy status, and crown dieback. These data suggest that lightning strikes often cause substantial canopy disturbances with implications for forest recovery and diversity.

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Topography as a barrier against fire spread in the Ecuadorian Andes

Presenter: Pablo SARANGO HIDALGO

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Fire behavior - intensity, rate of spread, and severity - are influenced by weather, fuels, and topography. Of these factors, topography acts as the underlying foundation. It provides a relatively stable template upon which vegetation dynamics, climate, weather, and fire may respond. To identify topographic features that limit wildfire spread in Ecuador's inter-Andean region, I employed a combination of data sources. This included Global Annual Burned Area Maps (GABAM) from 2015 to 2020, a Digital Elevation Model (DEM), and the Normalized Difference Vegetation Index (NDVI). Each burned area from the GABAM data was divided into two zones: the boundary of the burned area itself and a surrounding perimeter. I then converted the pixel data from both zones into polygons and calculated the Topographic Roughness Index (TRI), slope, and aspect from the DEM. Additionally, NDVI values were assigned to each polygon. Polygons with NDVI values < 0.5, indicating minimal vegetation, were excluded from further analysis. The analysis revealed significant differences between the two zones for the variables examined. Fire perimeters were typically found in areas with:

• Elevation: 2800-3300 meters
• TRI: 17-44
• Slope: 20-55 degrees
• Aspect: East-West By gaining a deeper understanding of fire extinguishers in the Tropics, we can refine fire and fuel management strategies. This will not only promote the restoration of natural successional patterns and ecological resilience in fire-prone forests, but also improve risk assessment and achieve ecological benefits during active fire management.

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Increasing liana density reduces canopy height and carbon storage potential in an old growth Neotropical forest

Presenter: David M. DEFILIPPIS

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Tropical forests store approximately 40% of the worldwide terrestrial aboveground carbon and are critical for the global carbon cycle. Lianas have been shown to limit the ability of tropical forests to uptake and store carbon through intense competition with trees. The increase in liana density in tropical forests has been hypothesized to further reduce the capacity of tropical forests to store carbon; however, no studies have examined whether lianas actually do so. We studied the effects of increasing liana density on the change in forest carbon storage on the BCI 50-ha plot using three related metrics of forest carbon storage: canopy height, canopy tree size, and canopy tree number. We used two censuses 10-years apart of the rooted liana (2007-2017) and canopy tree stems (2005-2015), as well as two LiDAR census (to determine canopy height dynamics 2009-2019) in the BCI 50-ha plot. We found that canopy height decreased most in areas where rates of liana density increase were highest. Likewise, canopy tree above ground biomass decreased and canopy tree density increased in these same areas of liana increase. These data suggest that in areas of increasing lianas, forest canopy height decreases and there are more but smaller canopy trees, ultimately reducing the carbon storage capacity of the BCI forest.

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Soil water availability and depth of tree and liana root water extraction across the Panamanian Isthmus during the 2024 extreme El Niño

Presenter: Alfonso J. ZAMBRANO

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Soil water availability regulates ecosystem function during drought. Tropical plants that can access reliable soil water sources found at depth may avoid experiencing hydraulic failure during extended drought periods, such as those during El Niño climate events. We used a combination of soil water content and soil water potential measurements to calibrate a soil biophysical model in HYDRUS, as well as stable water isotopes in soil and plant xylem and inverse rooting depth modeling results to characterize species-specific patterns of vertical soil water extraction by canopy and subcanopy tree and liana species. Study sites span a twofold precipitation gradient in Panama, from San Lorenzo (SLZ; 3421 mm MAP) to Barro Colorado Island (BCI; 2600 mm) to Parque Natural Metropolitano (PNM; 1740 mm). In 2023 at BCI, upper soil water content ranged from 0.54 to 0.21 m3 m-3 (upper soil) and 45 to 0.55 m3 m-3 (soil >100 depth) during the wet-dry season, above the plant wilting point. During the 2024 El Niño event at the drier PNM site, soil moisture in the upper 10 cm dropped below 15 m3 m-3, well below plant wilting point. Due to observed differences in the vertical profile of soil texture, site-specific calibration of soil moisture is in progress. Initial isotope results from the BCI 2022 dry season indicated that as upper soil water availability declined, some species shifted root water uptake to deeper depths. Tree water isotopes were 2.5 to -3.0 ‰ for d18O and -3 to -30 ‰ for d2H and compared with soil isotopes revealed uptake depths from surface roots (e.g., Cordia sp.) to 50-100+ cm depth (e.g., Inga sp.). Data are being used to improve parameterization of earth system models, such as the land model in the US Department of Energy's Energy Exascale Earth System Model (E3SM) that will improve predictive understanding of the trajectory of climate change in the future.

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Observation-informed representation of tropical forest diversity at regional scale in terrestrial biosphere models

Presenter: Marcos LONGO

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Ongoing climate change is intensifying the frequency of hot droughts across tropical regions, which can lead to significant impacts on the structure, composition and function of tropical ecosystems. To reliably predict the response of tropical moist and dry forests to global change, it is critical that terrestrial biosphere models represent the diversity of individual trees' trade-offs between allocation of resources to growth and to drought tolerance. Over the past years, data availability on plant traits have significantly increased, providing an opportunity for constraining the representation of these trade-offs in vegetation demography models such as the Functionally Assembled Terrestrial Ecosystem Simulator (FATES). We pooled trait and allometry data from multiple open-source databases (including TRY, NGEE-Tropics and LT-Brazil) in the Neotropics, and used an unsupervised clustering approach to identify and implement plant functional types (PFT) along the main observed trade-off axes. The resulting PFTs were used across multiple mature forest sites along a precipitation gradient in the Neotropics and regionally across the tropical Americas. We found that FATES qualitatively represents biomass differences across dry and moist forests, but overestimates drought-deciduous abundance and underestimates evergreen PFT fractions under current climate. Our results hitherto indicate a potential for advancing understanding of PFT coexistence across the tropics using observed traits; however, they suggest that additional data and model process development are needed to quantitatively improve the model predictions.

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Plant defense chemistry of woody seedlings varies with life history

Presenter: Damla CINOGLU

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Insect herbivory drives mortality for tree seedlings in the tropics and has been providing selective pressure on leaf chemistry at evolutionary timescales. Major variation in leaf chemistry has been attributed to interspecific differences, instead of intraspecific differences along leaf ontogeny, light environment, and season. With fast-growing species accumulating higher herbivory damage, are species grouped by their life history strategies consistently over or under investing in leaf chemical defenses? We collected young and mature leaves from 3-5 tree seedlings of 64 species that vary in their life history strategies (growth-survival and stature-recruitment tradeoffs) on Barro Colorado Island (BCI), Panama in 2023. Samples were analyzed using ultra high-performance liquid chromatography (UHPLC) and tandem mass spectrometry (MS/MS) (Sedio et al. 2017). This process identified 111,171 compounds (36,661 secondary metabolites) derived from pooled leaf samples of 472 individuals. Linear mixed effects models, including species as a random effect, showed that a species' position along the growth-survival tradeoff ($p = 0.0331$), and not the stature-recruitment tradeoff, explained significant variation in secondary metabolomic compound richness. Furthermore, young leaves of fast-growing species ($p = 0.0251$, high growth, low survival) but not long-lived pioneers (high growth, high survival, low recruitment) had higher secondary metabolomic compound richness than slow-growing species (low growth, high survival). Our current results suggest that there are patterns of chemical variation among life history strategies. Ultimately, we are excited to extend this work to include comparisons of leaf defense chemistry across seedlings and adults of the same species. This work has implications for a mechanistic understanding of niche differentiation in the forests of BCI.

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Estudio de comunidades de hongos endófitos foliares asociados a 16 especies de plantas muestreadas en cafetales de Renacimiento y Parque internacional La amistad, Chiriquí, Panamá

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Los bosques tropicales albergan una gran diversidad de vida, incluyendo una amplia variedad de hongos endófitos asociados a las plantas que los habitan. El término endófito se refiere a cualquier microorganismo, bacteria u hongo, que vive dentro de tejidos vegetales sin causar daño aparente. Los árboles tropicales tienen una alta diversidad de hongos simbiontes y se consideran puntos críticos para la diversidad de especies de hongos endófitos. Con el fin de identificar la composición taxonómica de comunidades de hongos endófitos foliares de C. arabica y comparar estos taxones con los encontrados en otras especies de plantas presentes en cafetales y bosques circundante, se utilizó la herramienta de metabarcoding de hongos. Se analizaron muestras de hojas, distribuidas en cinco divisiones: Magnoliophyta, Pinophyta, Monilophyta, Bryophyta, y Cycadophyta. Mediante una secuenciación masiva del locus ITS2. Las plantas fueron identificadas mediante claves taxonómicas y mediante secuenciación de los loci rbcL y MatK. Se identificaron un total de 9435 variantes de secuencias de amplicones (ASVs), destacando las clases de hongos: Dothideomycetes, Sordariomycetes y Eurotiomycetes, como las más dominantes. Las estimaciones de diversidad alfa mostraron diferencias significativas entre especies (Kruskal-Wallis H, $p<0.01$). Del mismo modo, los análisis de beta diversidad mostraron diferencias significativas entre sitios (Permanova: $p<0.001$). En la caracterización molecular, se obtuvo secuencias para barcoding de los genes matK y rbcL para *C. valerioi, P.juruana, O. whitei, D.maxonii* y *Z. pseudomonticola.* Los resultados de este estudio nos brindan una mejor comprensión sobre la distribución de especies de hongos endófitos en plantas de café y plantas nativas. Además, nos permite hacer recomendaciones acerca de qué especies de plantas nativas podrían actuar como donantes de hongos endófitos benéficos para el cultivo de *C. arabica*, y entender las relaciones ecológicas entre estas comunidades y con sus plantas hospederas.

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You eat what you hear: Hearing sensitivity as an underlying mechanism for niche differentiation in gleaning bats

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Tropical ecosystems are known for their high species diversity. Different adaptations enable species to coexist and thus permit niche differentiation. Historically, research focused primarily on morphological and behavioral adaptations for foraging, roosting, and other basic ecological factors. Another important factor, however, is differences in sensory capabilities. So far, studies mainly have focused on the output of behavioral strategies of predators and their prey preference. Understanding the coexistence of different foraging strategies, however, requires understanding underlying cognitive and neural mechanisms. The neotropical leaf-nosed family Phyllostomidae is ecologically highly diverse, with several species co-existing in the same habitat. We investigated the hearing in bats and how it shapes their co-existence. We present the hearing thresholds and echolocation calls of 12 different gleaning bats. In our study we measured their auditory brainstem responses to assess their sensitivity thresholds and dynamic responses to different acoustic stimuli. The audiograms of the 12 gleaning bat species had similar overall shapes but differed in slopes and sensitivity peaks. The bats' hearing sensitivities differed mainly in the low frequency range for frequencies below 9 kHz and in the high frequency range for frequencies of their echolocation calls. Our results suggest that differences in hearing abilities among bats contribute to the diversity we see in foraging strategies of gleaning bats. We argue that differences in auditory sensitivity and hearing can be a key mechanism explaining diversity in sensory niches and coexistence of species.

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Panama tropical forest soils as a model field system for ecological studies of protists

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Protists are key contributors to belowground food webs through diverse roles as decomposers, predators, and parasites. Because tropical soils across Panama vary in biogeochemical properties, we can use the gradients of variables to understand the environmental drivers of soil protists. From soils previously collected in from long-term plots across a rainfall gradient in Panama, we uncovered biotic and abiotic parameters that shape the distribution of Apicomplexa, a dominant group of soilborne parasites. The composition of Apicomplexa lineages (from 171 soils) was driven by several abiotic factors including soil pH, mean annual temperature, and mean annual precipitation. Using network analyses, we also uncovered Apicomplexa lineages that were tightly linked to specific Metazoan lineages including Arthropoda, Annelida, and Nematoda. These may reflect putative host associations, or shared preferences for similar abiotic variables. Other protists, including many amoebae, are 'top-down' consumers of bacteria and fungi in soils. By feeding on the primary consumers in the soil food web, amoebae likely regulate the fungal and bacterial energy channels that contribute to broader ecosystem dynamics. Despite their importance the contributions of predatory amoebae to soil processes remain mostly unknown. The limited genomic representation of most soil amoebae hinders our ability to understand their metabolic contributions to ecosystem processes. Sampling across diverse soils in Panama, we will profile the most abundant amoebae using culturing and genomics. Collectively, our efforts will shed light on the diverse ways in which protists contribute to tropical forest ecosystems.

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Análisis de capacidades y logros funcionales en la iniciativa de reforestación de la Comarca Ngäbe-Buglé a través del enfoque de Amartya Sen

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La Iniciativa de Reforestación de Rohr (RRI) del Instituto Smithsonian de Investigaciones Tropicales (STRI) tiene como objetivo principal avanzar en la ciencia de la restauración forestal para beneficiar a comunidades rurales e indígenas empobrecidas, especialmente en la lucha contra el cambio climático. Entre sus metas se encuentran establecer plantaciones de enriquecimiento de bosques secundarios para secuestrar dióxido de carbono y mejorar los medios de vida, así como empoderar a estas comunidades. La RRI se está implementando en la Comarca indígena Ngäbe-Buglé, una de las siete divisiones políticas especiales de tipo provincial que alberga comunidades ancestrales en Panamá. Esta comarca enfrenta los más significativos desafíos en términos de desarrollo humano, según el Programa de las Naciones Unidas para el Desarrollo (PNUD) en 2014. En este contexto, el objetivo principal de esta investigación es describir las capacidades de desarrollo humano y los logros funcionales de la comarca Nägbe-Buglé del distrito de Nürüm. Para lograrlo, usaremos la caracterización socioeconómica de la Iniciativa de Reforestación de Rohr, lo que nos permitirá identificar los los indicadores y las dimensiones de las capacidades de la comunidad. Además, evaluaremos en qué medida estas capacidades afectan los logros funcionales, utilizando el enfoque de Amartya Sen como marco teórico. Los resultados de esta investigación serán fundamentales para comprender la importancia de reconocer las capacidades y logros funcionales de las poblaciones locales, rurales y comunidades indígenas en los procesos de reforestación. Esto permitirá garantizar los beneficios a largo plazo y asegurar el propósito de la iniciativa de reforestación en la comarca.

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The Bacurú Drõa plot, Darien: Bringing BFDP science to people

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The power of plots such as BFDP, and plot networks, such as ForestGEO, to address a range of ecological issues has been clearly demonstrated. Our research sheds light on social benefits arising from bringing such science to people. Beginning in 2022, staff of the BFDP trained Embera technicians who have now established a 15-hectare permanent plot, the Bacurú Drõa (Old Forest in Embera) plot, on their territory in Darien. In Panama, Indigenous territories overlap with remaining natural lands and yet they do not derive benefit from their role of forest guardians. Furthermore, highly forested regions such as Darien are often plagued with illicit activities increasing the vulnerability of youth. The Bacurú Drõa plot forms the heart of a Participatory Old-growth Forest Observatory developed as a proof of concept for the fact that the full participation of Indigenous peoples in research could yield a range of benefit for the science and the communities. The key values of applying the BFDP methodology in a social-ecological landscape are: (1) access to a region otherwise too remote and difficult to allow scientific work. Indeed, the data set created by the Bacurú Drõa plot is the most comprehensive tree inventory of this global biodiversity hotspot. (2) Improvement of the local economy with 252 local people working for the project (cooks to technicians); (3) Training for more than 50 youth, women and men, not only as field technicians but also using GPS and QGIS, entering data in the computer, and flying a drone; (4) Diffusion of traditional knowledge with Embera “botanicos” identifying 90% of all trees into 258 Embera tree types. The Bacurú Drõa plot, established with the Traditional Embera Authorities of Balsa, clearly provides a blueprint for the effective engagement of Indigenous people in science and points to a possible future for research started with BFDP. By providing licit employment and valuing the contribution of the Embera to science, our participatory action research methodology contributes to the conservation of this large (125,000 ha) high conservation value (FLII > 0.9) territory. We believe that it can inform global monitoring initiatives through the demonstration of the benefits incurred by engaging with local communities.

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Connecting communities with nature: STRI Education & Public Program Initiatives

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The education and public programs at the Smithsonian Tropical Research Institute (STRI) embody the institution's commitment to advancing knowledge and fostering understanding of tropical ecosystems. These informal science education programs are meticulously designed to prioritize both content knowledge and practical skills while employing innovative pedagogical methodologies to engage learners effectively. Through its public program stations, STRI enriches the educational experience by offering live exhibits and interactive educational activities, which serve as dynamic platforms for experiential learning. Guided tours led by experienced docent guides provide visitors with in-depth insights into tropical biodiversity and research that leads to conservation efforts. These tours not only educate but also inspire curiosity and appreciation for the natural world. Inspired by the Q?rius program at the SI National Museum of Natural History (NMNH), STRI integrated the Q?rioso programs, a set of education programs that offer diverse audiences an opportunity to discover the amazing wonders of tropical ecosystems and its biodiversity. Through the exploration of objects, scientific tools, and artifacts, the Q? programs provide hands-on learning opportunities and effectively promote and nurture a passion for scientific inquiry and environmental stewardship. A yearly professional development program for public school teachers is central to STRI public programs. Recognizing educators as key agents of change, STRI offers training workshops and resources to enhance their capacity to effectively teach about tropical biodiversity and conservation. Through these programs, teachers gain access to cutting-edge scientific research, pedagogical strategies, and hands-on activities that they can integrate into their classrooms. Through mobile education programs, STRI facilitates immersive experiences that bring the wonders of tropical biodiversity directly to schools, community centers, and events. These initiatives leverage interactive STEM activities and educational materials to foster curiosity and understanding among young participants. These programs transcend geographical boundaries, reaching communities beyond traditional visitor centers. Furthermore, adding new exhibits at STRI stations, integrating art and math into the existing public program curriculum, expanding collaborations with new partners, and upgrading programming initiatives, continually enhance the educational landscape at STRI, ensuring that the programs remain relevant and engaging.