



SEED DISPERSAL IN THE ANTHROPOCENE

Kulpat Saralamba

**7th Frugivores and
Seed Disersal Symposium**
2-6 March 2020
Corbett Landscape, India



SCHEDULE and ABSTRACTS

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About the conference

The Frugivores and Seed Dispersal Symposium, held once in 5 years, strives to bring together the leading edge of global research on the understanding of seed dispersal. The seventh edition of the FSD Symposium will be held within the Corbett Tiger Reserve landscape in northern India. This spectacular landscape is home to tigers, elephants, deer, langur and over 400 species of birds. The conference will be hosted at the Taj Corbett Resort & Spa, located in Uttarakhand, one of India’s Himalayan states. The venue is adjacent to the Corbett National Park – India’s first national park – where you can spot elephants, deer, leopards, red foxes, sloth bear and the regions’ most famous resident, the Royal Bengal Tiger. The host resort is located in a village surrounded by dipterocarp “sal” forests, along the banks of the Kosi River, and offers easy access to various tropical and temperate ecosystems that characterize the outer Himalayan formations.

Conference website: <https://fsd2020.wordpress.com/>

ORGANISERS & MEDIA PARTNER



**nature
conservation
foundation**



**Azim Premji
University**





Organising Committees

Organising Committee:

Soumya Prasad (Chair, NSI), Renee M. Borges (CES), Aparajita Datta (NCF), Divya Mudappa (NCF), Sindhu Radhakrishna (NIAS), Jayanti Ray Mukherjee (APU), Asmita Sengupta (ATREE), Ghazala Shahabuddin (CEDAR), Sachin Sridhara (NCBS), H.S. Sushma (SACON)

Scientific Committee:

Soumya Prasad (Chair), Kim McConkey (Co-Chair), Eliana Cazetta (Co-Chair), Ahimsa Campos-Arceiz, Tomás Carlo, Pierre-Michel Forget, Mauro Galetti, Pedro Jordano, Beth Kaplin, Rohit Naniwadekar, Onja Razafindratsima, David Westcott

Local facilitators:

Avisfera Adventures



About the Venue

FSD 2020 is being organized along the edge of the Corbett National Park, India's first National Park (est 1936). Corbett is located in the Himalayan state of Uttarakhand in northern India, about 270 km north of New Delhi, which is the nearest International Airport. The Corbett landscape has rich nature, culture and history.

The 1318-km square park and the surrounding forest divisions is spread across "bhabhar", "Shiwalik" and outer Himalayan formations. The extensive dipterocarp "sal" forests are interspersed with mixed tropical dry forests, which give way to pine forests above 1000 m. This landscape is very rich in large mammal and bird diversity, and is home to elephants, tigers, several deer, primates and over 400 species of birds. March is the perfect time to be in the Corbett landscape, within the spring season here. The dry forests are bursting with colour, with migrant birds starting to leave for their higher Himalayan homes. The conference will be hosted at the Taj Corbett Resort, with additional accommodation in the adjoining the Riverview Retreat-Corbett. Closest International Airport: Indira Gandhi International Airport, New Delhi. Several airport hotels are available close to the Indira Gandhi International Airport at New Delhi.

Conference Transfers: Shuttle buses will be arranged periodically from the Indira Gandhi International Airport to the host resorts in Corbett landscape, Uttarakhand. The shuttle timings will be tuned to the arrival and departure schedules of the conference participants.

Contact:

Taj Corbett Resort

Zero Garjia, Dhikuli Ram Nagar ,

Jim Corbett , Uttarakhand 244715

India

+91 5947-266600 , +91 5947-7455028252 , +91 5947-7455028253

reservations.corbett@tajhotels.com



(c) Alicia Solana Mena

Pre-conference day trip

Conference participants will be taken to one of the ranges in Corbett National Park in the morning hours of the 2nd of March, 2020. If you are opting for the pre-conference day trip, you will need to **arrive in the Corbett landscape before 6 AM on the 2nd of March**. Contact Avisfera if you need to book a room reservation for the previous night (1st March, 2020). If you wish to stay elsewhere, we would recommend checking out Camp Hornbill or Jim's Jungle Retreat. Those staying outside the conference venues, you will have to arrive by 6 AM at the conference venue to join the day safari. Please note: Day safari into the national parks involves obtaining permissions and national park reservations. Last minute requests cannot be accommodated in the safari. Please reserve your slot as early as possible. Please reserve your slot for the pre-conference day trip when you fill the registration form, or contact Avisfera before Jan 2nd, 2020.

Trip details:

Date - 2 March 2020

Start time: 06:00 am

Start venue: Taj Corbett Resort

Contact Avisfera:

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(c) Rohit Naniwadekar

SCHEDULE

Schedule at a glance

Opening day: 2 March 2020

12:00-14:00	Registration opens
14:10-14:25	Introduction to the Meeting
14:25-15:25	Opening Plenary
15:25-16:00	Symposium
16:00-16:30	Tea
16:30-17:30	Symposium
17:30-18:00	Oral presentations
18:00-21:00	Dinner

Daily schedule - 3-5 March 2020

07:00-08:30	Breakfast
08:30-10:30	Symposia
10:30-11:00	Tea
11:00-12:00	Symposia/Oral presentations
12:00-13:00	Plenary
13:00-14:00	Lunch
14:00-16:00	Symposia/Oral presentations/Speed talks
16:00-16:30	Tea and posters
16:30-17:30	Oral presentations / Symposium
17:30-18:30	Plenary
18:30-21:00	Dinner (Special dinner on 5 March 2020)

Concluding day: 6 March 2020

07:00-08:30	Breakfast
08:30-10:15	Symposium and oral presentation
10:15-10:45	Tea
10:45-11:45	Closing Plenary
11:45-12:00	Closing remarks, meeting ends
12:30-13:30	Lunch

Detailed Schedule

2 March 2020 Seed dispersal in the Anthropocene		
12:00-14:00 Registration		
14:00-14:15	Meeting Opens: Introduction by Soumya Prasad	
14:15-15:15	Opening Plenary Rohit Naniwadekar Understanding the role of large-bodied frugivores in seed dispersal	
15:15-17:20 Symposium: Anthropogenic interference of animal seed dispersal: from cities to farms		
15:15-15:20	Tiziana Gelmi-Candusso	Seeds and the city: The interdependence of zoochory and urban ecosystem dynamics, and its implications
15:20 - 15:35	Vuyisile Thabethe	Ingestion by an invasive parakeet species reduces germination success of invasive alien plants relative to ingestion by indigenous turaco species in South Africa
15:35-15:50	Purabi Deshpande	The role of urban avian frugivores in dispersal of horticultural introductions
15:50-16:05	Asmita Sengupta	Frugivory by macaques across varying levels of anthropogenic interference
16:05-16:30 Tea break		
16:30-16:45	Kadambari Deshpande	Forbidden fruits? Benefits and costs of seed dispersal by bats in agroforestry landscapes of India's Western Ghats
16:45-17:00	Anusha Krishnan	Constraints for population genetic variation via dispersal in a concrete jungle
17:00-17:15	Gitanjali Katlam	Understanding foraging behaviour of frugivores species at garbage dumps
17:15-17:45 Oral presentations : Elephants		
17:15-17:30	Tan Wei Harn	Long-term monitoring of seed dispersal by Asian elephants in a Sundaland rainforest
17:30-17:45	Alicia Solana Mena	Elephant frugivory and wildboar seed predation of <i>Irvingia malayana</i> , a large-fruited tree, in a rainforest of Peninsular Malaysia
17:45-18:30	Special talk Vijay Dhasmana Rewilding in urbanscapes of the Aravallis, India	
Dinner		

3 March 2020 Evolution and Natural History		
08:30-10:30 Symposium: Perspectives and Advances: The Role of Seed Dispersal in Plant Populations		
08:30-08:45	Noelle Beckman	Advancing an interdisciplinary framework to study seed dispersal ecology
08:45-09:00	Eugene W. Schupp	Intrinsic and Extrinsic Drivers of Intraspecific Variation in Seed Dispersal Are Diverse and Pervasive
09:00-09:15	Landon R. Jones	SEADS, a simulation modeling framework to compare spatial patterns of seed deposition by sympatric animal dispersers
09:15-09:30	Jadelys Tonos	Individual networks of plant-animal interaction: Insights into spatial structure and influencing factors
09:30-09:45	Tomás A. Carlo	Understanding frugivory and seed dispersal as an informatic process
09:45-10:00	Charles Kwit	The role of seed disperser macro- and micro-biomes and chemicals on the seed dispersal loop
10:00-10:15	Liba Pejchar Goldstein	Predicting the effects of climate change on fruiting phenology
10:15-10:30	Pedro G. Blendinger	Maximization of energy or nutrient balancing: the interplay between fruit chemical content and foraging behaviour in fruit-eating birds
10:30-11:00 Tea Break		
11:00-12:00 Symposium: Epizoochory and endozoochory, two linked facets of seed dispersal		
11:00-11:15	Shumpei Kitamura	Quantifying external seed dispersal by terrestrial mammals using camera trap data in a Japanese cedar plantation, central Japan
11:15-11:30	Thabiso M Mokotjomela	Epizoochorous dispersal of emerging alien cactus species: <i>Cylindropuntia pallida</i> F.M. Knuth, in the arid areas of South Africa
11:30-11:45	Andy J. Green	Internal and external dispersal of plants by waterbirds
11:45-12:00	Christophe Baltzinger	Complementarity of seed dispersal mechanisms mediated by ungulates
12:00-13:00	Plenary Kim Valenta and Omer Nevo Animal-plant communication: the evolution of fruit signals	
13:00-14:00 Lunch		

14:00-15:15 Oral presentations: Evolution & Ecology		
14:00-14:15	Brittany Cavazos	Plants alter some fruit traits under different simulated frugivory rates
14:15-14:30	Elise Sivault	The body weight and skull measurements predict seed dispersal capacity in bat, primate and carnivore species.
14:30-14:45	Tobias Nicolas Rojas	Frugivores' morphological and chemical interaction niches relationship: It is not what it looks like
14:45-15:00	Paulina Celebias	Consequences of intraspecific variation in seed size: does small seeds enhance the survival of large ones?
15:00-15:15	Manuel Nogales	A global review of frugivory and seed dispersal on islands
15:15-15:45 Speed Talks		
	Tamara Burgos	The Iberian lynx (<i>Lynx pardinus</i>) as a modeler of seed dispersal through trophic cascades
	Sara Beatriz Marques Mendes	Is there a seed dispersal crisis in Europe?
	Kazuaki Takahashi	Vertical seed dispersal of Japanese crowberry by Japanese black bears and birds: estimation using stable oxygen isotope ratios.
	Giovanni Villa	Exploring the role of <i>Macaca nemestrina</i> as seed disperser
	Tinyiko Cavin Shivambu	Feeding biology of invasive rose-ringed parakeets <i>Psittacula krameri</i> in urban landscapes of eThekweni Metropole, KwaZulu-Natal Province, South Africa
	Nasiphi Bitani	Dispersal of invasive <i>Lantana camara</i> by native bird species in KwaZulu-Natal, South Africa
	Islamiat Abidemi Raji	The role of avian frugivores in the germination of keystone <i>Ficus</i> species in KwaZulu-Natal, South Africa
15:45-16:30 Tea and Special showing of all posters (Main Lawn)		
16:30-17:30 Oral presentations: Natural History & Ecology		
16:30-16:45	Kahoko Tochigi	Difference of deposition site quality among frugivorous mammals in vertebrate seed dispersal
16:45-17:00	Yamato Tsuji	Age difference in seed dispersal parameters found in Japanese macaques (<i>Macaca fuscata</i>)
17:00-17:15	Bernardo Clausi	Bare throated bellbird ecology and rainforest tree diversity
17:15-17:30	Alberto García-Rodríguez	The role of the brown bear as a seed disperser: A review
17:30-18:30	Plenary Andy J Green Avian endozoochory of plants lacking a fleshy-fruit : a major dispersal mechanism	
Dinner		

4 March 2020 ECOLOGY		
08:30-10:30 Symposium: Seed dispersal mismatches: when phenology matters		
08:30-08:45	Shoji Naoe	Phenology as a driver of local and long-distance seed dispersal by animals
08:45-09:00	Haruko Ando	Potential of inter-island seed dispersal by Japanese wood pigeon in relation to their movement pattern and fruiting phenology
09:00-09:15	Beth Kaplin	Phenology and seed dispersal patterns in a tropical montane forest, Rwanda.
09:15-09:30	Vivienne Loke Pei Wen	Fruiting phenology and food availability for the Belum Tropical Rainforest Community
09:30-09:45	Mario Pesendorfer	The effects of variation in seed crop size and phenology and dispersal kernels of seeds and seedlings in montane old-growth forests
09:45-10:00	Michał Bogdziewicz	Climate warming disrupts mast seeding and its fitness benefits in European beech
10:00-10:15	Spencer C. Schubert	Temporal Dynamics of plant-frugivore networks in the tropical wet forests of Hispaniola
10:15-10:30	Irene Mendoza	Temporal dynamics of seed-dispersal networks mediated by plant phenology in a Mediterranean scrubland
10:30-11:00 Tea Break		
11:00-12:00 Oral presentations: Ecology		
11:00-11:15	Simon D. Stringer	Interpretation of the role of frugivores in seed germination potential dependent on study design
11:15-11:30	Andrea Blackburn	Orangutan Seed Dispersal in Gunung Palung National Park, Borneo, Indonesia: Dispersal Quantity, Germination Rates, Gut Transit Times, and Dispersal Distances
11:30-11:45	Alexander V. Christianini	Temporal variation in the effectiveness of seed dispersal in a Neotropical savanna

11:45-12:00	Mariana Lopes Campagnoli	Fruit crop size and diversity of visiting birds enhance seed dispersal effectiveness
12:00-13:00	Plenary Juan Morales Movement, frugivory and seed dispersal	
13:00-14:00	Lunch	
14:00-16:00	Symposium: How a network approach advances our understanding on seed dispersal interactions in a changing world	
14:00-14:15	Pâmela Friedemann	Palm tree-bird interaction network: do bird species and their roles change with Atlantic Forest types in southeast Brazil?
14:15-14:30	Erison Carlos dos Santos Monteiro	Evolutionarily distinct interactions, seed-dispersal networks and landscape fragmentation in a hotspot of biodiversity
14:30-14:45	Nancia Raoelinjanakolona	Impact of habitat fragmentation on plant-frugivore mutualistic networks
14:45-15:00	Isabel Donoso	Downsizing of animal communities triggers stronger functional than structural losses in seed-dispersal networks
15:00-15:15	Ruben Heleno	The disruption of São Tomé seed-dispersal networks by alien vertebrates
15:15-15:30	Anna Traveset	Mammal seed-dispersal networks in changing Mediterranean ecosystems
15:30-15:45	Alba Costa	The restoration of seed dispersal networks in Seychelles
15:45-16:00	Elena Quintero	Super-generalist species in ecological networks: the role of biological traits in individual interactions
16:00-16:30	Tea and Posters (ECOLOGY)	
16:30-17:30	Symposium: How a network approach advances our understanding on seed dispersal interactions in a changing world	
16:30-16:45	Sandra Hervías-Parejo	Bird functional traits as drivers of interlinked pollination and seed dispersal networks
16:45-17:00	Ana Cristina Vara Crestani	Interindividual variations in plant and fruit traits affect the structure of a plant-frugivore network
17:00-17:15	Jorge Isla	Seed dispersal by animal frugivores and range expansion in plants: a multilayer network approach.
17:15-18:15	Plenary Susan Whitehead The diversity unseen: fruit phytochemical complexity and seed dispersal	
Dinner		

5 March 2020 CONSERVATION		
08:30-10:30	Symposium: Non-native frugivores and seed dispersal in novel ecosystems of the Anthropocene	
08:30-08:45	Ann Marie Gawel	Non-native mammals as seed dispersers or seed predators in a novel ecosystem
08:45-09:00	Samuel B. Case	Functional changes in assemblages of avian frugivores following extinction and invasion
09:00-09:15	Colleen T. Downs	Role of native avian frugivores in germination facilitation and potential dispersal of invasive American bramble (<i>Rubus cuneifolius</i>) in South Africa
09:15-09:30	Lindelwa S. Msweli	Fruit consumption of lantana (<i>Lantana camara</i>), bugweed (<i>Solanum mauritanium</i>), syringa (<i>Melia azedarach</i>) and cochineal prickly pear (<i>Opuntia monacantha</i>) by exotic and indigenous southern African ungulates
09:30-09:45	Elisabet V. Wehncke	Seed dispersal by fishes in rivers of Central Mexico tropical dry forests
09:45-10:00	David L. Vergara-Tabares	Seed dispersal of a native tree is promoted by the invasion of ornithocorous shrubs and modulated by their density
10:00-10:15	Geetha Ramaswami	Dispersal by native frugivores affects management of an invasive plant species
10:15-10:30	Evan Fricke	Introduced species in plant-frugivore networks: assessing impacts on network biogeography and predicting interactions under climate change
10:30-11:00	Tea Break	
11:00-12:00	Oral presentations: Conservation	
11:00-11:15	David A. Ehlers Smith	Effects of forest fragmentation on avian frugivore community assemblages in Indian Ocean Coastal Belt Forest, KwaZulu-Natal Province, South Africa
11:15-11:30	Pierre-Michel Forget	Roads disrupt seed dispersal in animal-mediated plants in tropical forests
11:30-11:45	Marcelo Tabarelli	Leaf-cutting ants as a key sink for seeds and seedlings in neotropical human-modified landscapes

11:45-12:00	Inara Roberta Leal	Myrmecochory in the Brazilian Caatinga and its response to anthropogenic disturbance and climate change
12:00-13:00	Plenary Haldre Rogers Strategic rewilding to restore seed dispersal to a defaunated island	
13:00-14:00	Lunch	
14:00-16:00	Symposium: Two sides of the coin: Defaunation and rewilding effects on frugivory and seed dispersal processes	
14:00-14:15	Nacho Villar	The ecological consequences of defaunating complementary frugivore functions
14:15-14:30	Junying Lim	Past and future extinctions shape the body size - fruit size relationship between palms and mammalian frugivores
14:30-14:45	Jose M. Fedriani	Intertwined effects of defaunation, increased tree mortality, and density compensation on seed dispersal across a heterogeneous landscape
14:45-15:00	Caroline M. Dracxler	Trait matching in Neotropical palm-frugivore interactions
15:00-15:15	Olivier Boissier	Modifications of the rainforest frugivore community are associated with reduced seed removal at the community level
15:15-15:30	Lisa Ong	Seed Dispersal Network of a Megafauna-rich Tropical Southeast Asian Rainforest
15:30- 15:45	Miyabi Nakabayashi	Even small seeds need large seed dispersers
15:45-16:00	Kim McConkey	The forgotten fauna: native seed predators on islands
16:00-16:30	Tea and Posters (CONSERVATION)	
16:30-17:00	Symposium: Two sides of the coin: Defaunation and rewilding effects on frugivory and seed dispersal processes	
16:30-16:45	Hugo Thierry	Strategic planning of rewilding of avian seed dispersers at different spatial scales
16:45-17:00	Carolina Bello	Rewilding defaunated Atlantic Forests with tortoises to restore lost seed dispersal functions
17:00-17:15	Luisa Genes	Effects of howler monkey reintroduction on ecological interactions and processes
17:15-17:30	Alessio Mortelliti	Food for thought: effects of personality on seed dispersal in modified landscapes
17:30-18:30	Plenary John Terborgh Seed dispersal and Janzen-Connell: how they interact	
Gala Dinner		

6 March 2020 CONSERVATION		
08:30 10:00	Symposium: Applications of frugivory and seed dispersal ecology for tropical forest restoration	
08:30-08:45	Juan P. González-Varo	Frugivorous birds operating as 'mobile links' in anthropogenic landscapes
08:45-09:00	Yvette C. Ehlers Smith	Trees alone don't make a forest: assessing factors influencing forest regeneration within a fragmented habitat mosaic.
09:00-09:15	Pedro Garrote	Seed dispersers inflate kinship in a bout, but promote genetic admixture within the neighbourhood in the long-term
09:15-09:30	Katherine Wynne	Quantifying seed rain patterns in a remnant and a chronosequence of restored tallgrass prairies
09:30-09:45	Anand Osuri	Patterns of tree regeneration in degraded rainforest fragments suggest declines in seed dispersal and a role for ecological restoration
09:45-10:00	Lauren Sullivan	Natural seed dispersal can promote diversity in grassland restorations when safe sites are available.
10:00-10:30	Tea Break	
10:30-11:30	Closing Plenary Eliana Cazetta Habitat loss drives plant-frugivore interaction loss in tropical forests	
11:30-11:45	Closing Remarks: Soumya Prasad	

POSTER SCHEDULE

3 March 2020: All Posters - special showing on main lawn

4 March 2020: ECOLOGY

Islamiat Abidemi Raji	The role of avian frugivores in the germination of keystone <i>Ficus</i> species in KwaZulu-Natal, South Africa (Speed Talk)
Balram Awasthi	Current status of frugivory and seed dispersal research in Nepal
Tamara Burgos	The Iberian lynx as a modeler of seed dispersal through trophic cascades (Speed Talk)
Puttaraju. K	Feeding habits of the great hornbill in Kaiga, Uttarakannada, Southern Western Ghats, India
Veronarindra Ramananjato	Smallest nocturnal primates facilitate seed germination and seedling growth in rainforests
Manpreet Singh	Role of small mammals in seed dispersal, predation and germination : A review
Kaori Takahashi	Morphological and nutritional characteristics of Japanese crowberry's berries that are used by Japanese black bears.
Kazuaki Takahashi	Vertical seed dispersal of Japanese crowberry by Japanese black bears and birds: estimation using stable oxygen isotope ratios. (Speed Talk)
Giovanni Villa	Exploring the role of <i>Macaca nemestrina</i> as seed disperser (Speed Talk)
Manqoba M. Zungu	Digestive efficiencies of frugivorous birds fed varying concentrations of equicaloric glucose and sucrose artificial fruit diets

5 March 2020: CONSERVATION

Puja Bishaya	Effect of local disturbance on frugivorous birds in fragmented tropical rainforests.
Nasiphi Bitani	Dispersal of invasive <i>Lantana camara</i> by native bird species in KwaZulu-Natal, South Africa (Speed Talk)
Eduardo Delgado Britez Rigacci	The resilient frugivorous fauna of a degraded forest fragment and its potential role in the enrichment of vegetation
Abhishek Gopal	Differential impacts of forest cover loss on frugivory and seed predation of four rainforest tree species in the southern Western Ghats, India
Dailos Hernández-Brito	The role of parrots as seed dispersers in the scenario of biological invasions
Abir Jain	Plant-seed disperser interactions in fragmented lowland tropical forests of north-east India
Laura Obando-Cabrera	Effect of disturbance on mutualistic networks of fruit bats in a tropical rainforest
José Otavio Venancio Ferreira	Induced Seed Dispersal by frugivorous vertebrates at a restored forest in southeastern Brazil
Sara Beatriz Marques Mendes	Is there a seed dispersal crisis in Europe? (Speed Talk)
Natalia Paes	How much the birds contribute for restoration areas?
Spencer C. Schubert	Artificial perches as a technique for enhancing tropical forest restoration
Tinyiko Cavin Shivambu	Feeding biology of invasive rose-ringed parakeets in urban landscapes of eThekweni Metropole, KwaZulu-Natal Province, South Africa (Speed Talk)
Cristiane Tibério Checon	The Picazuro pigeon: seed predator or unexpected disperser?
Yamato Tsuji	Seed dispersal by Japanese macaques inhabiting rural areas in central Japan
Suann Yang	Pre-dispersal frugivory and seed predation by insects in an invaded plant community



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PLENARIES

HABITAT LOSS DRIVES PLANT-FRUGIVORE INTERACTION LOSS IN TROPICAL FORESTS

ELIANA CAZETTA
06 March 2020

Forest loss can have strong negative impacts on species diversity, ultimately affecting key ecological processes such as seed dispersal. In this context, we assessed the effects of landscape-scale forest loss on frugivory and seed dispersal in 20 forest remnants of the Atlantic forest of the southern Bahia region, Brazil. The results showed that as deforestation progresses, vegetation structure of forest remnants shrinks, tree density and richness decrease and is ruled by a greater loss of species that can tolerate low levels of light, and are zoochoric-dispersed. The remaining forest harbors a lower amount of carbon and produces less fruit biomass with lower quality, thus affecting the local fruit-eating species such as frugivorous birds. Indeed, the diversity of forest-dependent frugivorous birds decreases with the simplification of forest structure and, increases with increasing fruit biomass in more forested landscapes. The most important results show the widespread effects of forest loss on plant-frugivore interactions in forest remnants. Our combined results revealed that habitat loss erodes the diversity of zoochoric trees, frugivorous birds, and their mutualistic interactions suggesting more profound effects on biodiversity than previously envisioned.

AVIAN ENDOZOOCHORY OF PLANTS LACKING A FLESHY-FRUIT : A MAJOR DISPERSAL MECHANISM

ANDY J. GREEN
03 March 2020

Given the dominance of plants lacking a fleshy-fruit outside of the tropics (e.g. in Europe, only 8% of angiosperms have a fleshy fruit), the extent to which endozoochory research is now focused on frugivores would probably surprise many pioneers in plant dispersal science. For example,

the seminal work of Vernon W. Proctor on avian endozoochory of a broad variety of plants published from 1959-1969 has been largely ignored. Focusing mainly on migratory waterbirds (waterfowl, shorebirds, gulls, storks...), I will outline why non-classical endozoochory (NCE) is a major dispersal process worthy of more attention. It provides dispersal distances greatly exceeding those assumed from fashionable dispersal syndromes. The role of NCE in enabling plants to readjust to climate change, and alien plants to spread, has been overlooked. I will argue that insufficient attention to NCE in recent decades has encouraged erroneous views amongst plant ecologists. I will explain why NCE means that (contrary to current opinion) it is unlikely that larger fruits/seeds are generally dispersed further, or that seeds are dispersed farther in the tropics than in temperate or extreme latitudes. Biotic and abiotic dispersal cannot be distinguished by simple inspection of fruit/seed morphology. Detailed morphological analysis suggests that seeds of fleshy-fruited and non-fleshy fruited plants are similarly adapted (or pre-adapted) for gut passage. Waterbirds disperse more species of terrestrial plants than aquatic plants, and NCE is largely a deterministic, mutualistic process that can be readily studied in the field. If we are to progress in our collective understanding of seed dispersal, we cannot afford to dismiss NCE dispersal as rare, unpredictable, serendipitous or "non-standard" events. At the same time, we must learn quickly from the inspiring work on frugivore-plant networks and expand such research into granivorous, herbivorous and omnivorous birds. I will review recent progress in that direction.

MOVEMENT, FRUGIVORY, AND SEED DISPERSAL

JUAN MORALES
04 March 2020

Here I review the connections between animal movement, frugivory, and seed dispersal. Modelling seed dispersal by animals seems straightforward: we need a way to keep track of the position of the animal through time and a clock for how long seeds

travel within the animal. Simple models show how changing parameter combinations can result in very different seed dispersal kernels, including fat-tailed ones. When movement is more realistic, in the sense that it is tied to the spatial distribution of resources, both seed consumption and dispersal kernels vary according to the neighborhoods of focal plants. Plants with many fruiting neighbors have high fruit removal rates but shorter dispersal distances. We empirically tested these theoretical predictions with a mistletoe species exclusively dispersed by an arboreal marsupial in Northern Patagonia. However, this is an unusual system because in general, plant communities interact with many species of frugivores. Recent empirical work shows that some frugivores may favor the consumption of rare fruits with important consequences for plant diversity maintenance. The mechanisms behind such patterns are still speculative but they could be related to frugivore physiology. Progress in hierarchical data analysis tools allows us to fit joint species frugivory models where species-level movement and foraging parameters are modelled as a function of species traits and their phylogenetic relationships. We have parameterized such models with bird movement and foraging data from tropical and temperate communities. In our model, plant-frugivore interactions emerge from frugivores' behavior in a spatially explicit setting. This allows predictions on how interactions rearrange after extinctions, and hence, to better quantify the vulnerability of plant species to partner loss. We can also have good estimates of a frugivores' role in seed dispersal. Overall, there has been great progress in data collection and modelling but we still need a better understanding of seed retention times, and of how bird physiology influences fruit choice. Further improvements in our ability to understand and predict seed dispersal by animals would probably also require considering agonistic behaviors within and among species.

UNDERSTANDING THE ROLE OF LARGE-BODIED FRUGIVORES IN SEED DISPERSAL

ROHIT NANIWADEKAR

02 March 2020

The role of large frugivores in seed dispersal is often difficult to evaluate as they often occur in low densities naturally or because they are threatened by hunting or habitat loss/degradation. Given their large gapes/mouths, they are thought to disperse seeds of a diverse array of fruit species and are important especially for large-seeded plants. However, their relative roles in larger plant-frugivore communities are poorly known. In tropical forests of Asia and Africa, hornbills are among the largest avian frugivores. They face significant threats because of hunting and/or habitat loss. In this talk, I will start by discussing the variation in fruit resource tracking mechanisms of sympatric hornbills at a tropical forest site in north-east India. I will then demonstrate the irreplaceable role they play in seed dispersal by showing their relative quantitative and qualitative contribution in seed dispersal vis-à-vis other avian frugivores. Ultimately, I will demonstrate the threats posed by hunting and habitat degradation on hornbills and the potential consequences for seed dispersal and plant regeneration.

STRATEGIC REWILDING TO RESTORE SEED DISPERSAL TO A DEFAUNATED ISLAND

HALDRE S. ROGERS

05 March 2020

Recent declines, extinctions, and range contractions of frugivores have highlighted the importance of animal-mediated seed dispersal for plant populations and communities. Restoration of ecological function requires rewilding of key species, often in the face of ongoing stressors, within heterogeneous and fragmented landscapes. As a result, successfully restoring ecological function is difficult, but islands provide an opportunity to develop strategies for restoration,

which may then be applied across larger areas. Here, we identify the importance of vertebrate frugivores for plant populations and communities using an accidental experiment: the invasive brown treesnake is responsible for the functional extirpation of all native vertebrate frugivores from the island of Guam. To determine how frugivores affect forest composition and structure, we compared Guam to nearby islands with vertebrate seed dispersers, using surveys, manipulative experiments, and a forest model. We demonstrate that Guam's forests will become less diverse and less able to recover from disturbance without vertebrate seed dispersers. We then developed a strategy to restore seed dispersal to Guam's forests. First, we assessed the seed dispersal effectiveness of native and non-native frugivores and selected the most effective as candidates for reintroduction. We then used a spatially-explicit model to identify the highest priority areas for rewilding and calculate the associated costs of invasive species control. Guam provides an unprecedented demonstration of the importance of seed dispersal, and a cautionary tale for systems experiencing defaunation around the world. Restoration of vertebrate seed dispersers in the presence of invasive predators may be an achievable goal on Guam and could serve as a guide for rewilding efforts in other places that are under threat.

SEED DISPERSAL AND JANZEN-CONNELL: HOW THEY INTERACT

JONH TERBORGH
05 March 2020

Ecologists have recognized for some time that the most critical stage of forest regeneration is the seed-to-sapling transition, as affirmed by the observation that species composition and species abundance relationships are established prior to the sapling stage. Understanding of the basic processes has exploded in recent years, allowing some generalizations to emerge. I shall provide support for the conclusions that follow, in most cases with evidence derived from research at the Cocha Cashu Biological Station in Perú. Seed limitation (failure of seeds of a given species to

arrive at an establishment site) is pervasive, being >99% in the tree species of median abundance. At Cocha Cashu, only 13 seeds of 2-3 tree species arrive at the average 0.5 m² establishment site each year. These give rise to one new seedling at the end of the ensuing dry season. Given that the tree community at Cocha Cashu includes more than 450 species, such a scant arrival of seeds suggests that "winner by forfeit" applies across the community. Undispersed seeds experience massive failure, approaching 100%, due to Janzen-Connell mortality agents. Dispersal kernels based on a focal tree model are thus misleading because they are comprised mainly of undispersed seeds. By separating dispersed from undispersed seeds, we have found that dispersed seeds fall at random in the forest with respect to conspecific adults. "Dispersal limitation," refers to the failure of seeds of a given species to arrive at a given site. We found strong dispersal limitation in gaps, especially of zoochorous seeds. More generally, dispersal limitation can be attributed to low fecundity and/or to inefficient distribution through dispersal. At faunally intact Cocha Cashu, distribution is excellent and dispersal limitation is almost entirely attributable to low per species fecundity. After 20 years of studying forest dynamics at Cocha Cashu, I can say that all phases of our work support the Janzen-Connell hypothesis. This is not to say that more investigation is not merited. Quite the contrary, our work has opened up new questions for future research that could add substantially to our understanding of high diversity tropical tree communities.

ANIMAL-PLANT COMMUNICATION: THE EVOLUTION OF FRUIT SIGNALS

KIM VALENTA AND OMER NEVO
03 March 2020

Flowers and fleshy fruits have evolved to attract animal visitors to promote pollination and seed dispersal and thus plant reproduction. In addition to direct rewards such as nutrients, both have evolved elaborate displays to signal their presence, location, and quality to animal mutualists. While extensive research over the past decades unveiled a tremendous diversity of visual and olfactory

adaptations in floral displays, the study of fruit traits lagged behind. Recent years have seen a growing interest in the evolution of fruit traits in the context of their interactions with seed dispersers. The talk will summarize recently published and unpublished data collected in various sites in Madagascar and continental Africa. It will present evidence that (a) fruit color has evolved to render fruits visually conspicuous, thus allowing animals to detect fruiting trees; (b) fruit scent has evolved to signal the ripeness of individual fruits, thus allowing animals to select fruits within a patch; and (c) some volatile chemicals in fruit scent are directly related to macronutrient content and may thus be honest signals for fruit quality.

THE DIVERSITY UNSEEN: FRUIT PHYTOCHEMICAL COMPLEXITY AND SEED DISPERSAL

SUSAN WHITEHEAD
04 March 2020

In a tiny sample of fruit pulp, there can be hundreds or even thousands of secondary metabolites. Six decades of research in chemical ecology has taught us that these metabolites play a vital role in plant interactions with the biotic and abiotic environment and, ultimately, influence the evolutionary trajectories of the organisms involved. Yet, most research in chemical ecology has focused on the secondary metabolites in leaves and their role in leaf defense, and comparatively little is known about the roles that secondary metabolites play in frugivory and seed dispersal. In this talk, I will review current knowledge on the ecological consequences of fruit secondary metabolites for plants, fruit pests/predators, and seed dispersers. Using interactions between neotropical *Piper* and frugivorous bats in the genus *Carollia* as a case study, I will show that fruit secondary metabolites can reduce damage from fungal pathogens and insect seed predators, affect seed disperser preference and physiology, and affect post-dispersal processes including secondary seed dispersal and seed germination success. Ultimately, I argue that the unseen chemical diversity of fruits

may be a critical determinant of the outcome of fruit/frugivore interactions and plant reproductive success. Furthermore, I will consider the hypothesis that the complex selective pressures on fruits, from both mutualists and antagonists, have been a dominant but underappreciated force in the evolution of phytochemical diversity at the whole plant level.



(c) Kulpat Saralamba

SYMPOSIUM

ANTHROPOGENIC INTERFERENCE OF ANIMAL SEED DISPERSAL: FROM CITIES TO FARMS

TIZIANA A. GELMI-CANDUSSO, VUYISILE THABETHE

02 MARCH 2020

During the last century of the Anthropocene, three quarters of the planet have been significantly transformed by human activity, including 97 percent of the most species-rich places on Earth. Urbanization, to meet housing demands for the increasing population number, and deforestation towards agricultural landscape, to sustain its nourishment demand, are the main drivers of such planetary scale interference. As a result, community assemblages have changed with pivotal effects on mutualisms, such as animal-mediated seed dispersal. Research into the consequences of anthropogenic interference on frugivory activity, plant phenology and the resulting seed dispersal outcomes is of crucial importance since viable seed dispersal processes are needed to maintain ecosystem dynamics and its biodiversity. Understanding the vulnerability of seed dispersal to human interference will lead the way to biologically relevant conservation measures. This symposium will update scientists on current research on the topic and stimulate much needed future collaborations to complement current research. Scientists attending the symposium will leave with a well-rounded knowledge on the on-going research concerning seed dispersal under highly invasive anthropogenic interference, the most current stage of the Anthropocene.

PERSPECTIVES AND ADVANCES: THE ROLE OF SEED DISPERSAL IN PLANT POPULATIONS

NOELLE G. BECKMAN, CLARE ASLAN, HALDRE ROGERS

03 MARCH 2020

Ecological understanding of dispersal has progressed by describing patterns of dispersal and the conditions under which they arise, advancing dispersal theory for populations and communities, and determining the effectiveness of seed dispersal. Nevertheless, the role of seed dispersal in the long-term spatial dynamics of plant populations remains poorly understood. The complexity and context-dependence of seed dispersal ecology challenges our ability to generalize across different systems and predict responses of plant diversity to global change. To move towards the predictive understanding necessary to inform conservation strategies requires a systematic examination of dispersal mechanisms and their influence on the persistence and spread of populations. This symposium convenes researchers representing a range of career stages that provide a diversity of perspectives and approaches in understanding the influence of dispersal on populations. The symposium begins with a discussion on promising interdisciplinary approaches for studying, generalizing, and predicting seed dispersal and its demographic consequences presented by Beckman. In this presentation, Beckman will describe a general approach for studying the context-dependency of seed dispersal, discuss strategies to reduce and embrace complexity, and encourage simultaneous and iterative data collection and model development. Schupp will delve into the intrinsic and extrinsic drivers of intraspecific variation in seed dispersal and discuss research needed to fill knowledge gaps. As a complement to this, Tonos will discuss novel experimental, simulation, and network approaches to gain a mechanistic understanding of the consequences of intraspecific variation for seed dispersal patterns. Carlo and Kwit will present promising new interdisciplinary tools (informatics and chemical ecology) in the study of seed dispersal. We close with a discussion on the consequences of climate change on phenology and dispersal presented by Pejchar.

EPIZOOCHORY AND ENDOZOOCHORY, TWO LINKED FACETS OF SEED DISPERSAL

**CHRISTOPHE BALTZINGER, SHUMPEI
KITAMURA, ANDY J. GREEN**

03 MARCH 2020

Recent reviews (Green et al. 2016 for waterbirds ; Albert et al. 2015, Baltzinger et al. 2019 for ungulates) and a few original papers (Costa et al. 2014 for migrating passerines ; Brochet et al. 2010, Reynolds and Cumming 2016 for waterbirds ; Couvreur et al. 2005, Benthien et al. 2016 for domestic ungulates) have assessed the relative contribution of both epizoochory and endozoochory for long distance seed dispersal. Except for the animal species included in these studies (i.e. wild and domestic ungulates, waterbirds and migrating passerines), there is a crucial lack of studies dealing with epizoochory (but see Kiviniemi and Telenius 1998 for rodents, Chen et al. 2018 for monkeys). Finally, studies considering the complete (including internal and external) seed load dispersed at the individual scale, and which may generate complex and unpredictable plant dispersal kernels, are also crucially missing. During this symposium, we would first like to present the current knowledge of epizoochory and introduce the groups of animals involved. We would like to fill the gaps identified, strengthen the place of epizoochory within the seed dispersal mechanisms, and encourage dialogue and further research. We also would like to deal with the complementarity between these two dispersal mechanisms and within guilds of seed dispersers. Because epizoochory and endozoochory are two linked facets of seed dispersal, and because each mechanism will differentially affect the diversity and the abundance of the seeds dispersed, as well as the seed dispersal effectiveness as a whole, we have to jointly consider both of them in a similar manner. Our aim here is to provide space for presentations for each group of seed dispersers : birds, primates, ungulates, rodents and others. Furthermore, taxonomic diversity also conceals diversity in functional traits (e.g. body mass, feeding regime, fur morphology, sociality) that may strongly affect the emigration, the transfer and the immigration of the seeds dispersed.

SEED DISPERSAL MISMATCHES: WHEN PHENOLOGY MATTERS

IRENE MENDOZA, KIM MCCONKEY

04 MARCH 2020

Biotic seed dispersal necessarily implies that the life cycles of interacting organisms, -i.e. their phenology-, temporally overlaps. Using a theoretical example, a frugivorous bird cannot disperse seeds of a plant if it has not fruited yet, and inversely, a plant cannot have its seeds dispersed by an appropriate frugivorous bird if the animal is not present in the area when fruits are available (and migrating elsewhere instead). Although this is a very basic requisite for biotic seed dispersal to take place, it is striking how a formal link between fruiting phenology and seed dispersal is lacking in current literature. Phenological studies normally use a perspective of climate change research and focus on the temporal variation of seed production in relation to environmental variables, but pay little attention to the implication for seed dispersers of these temporal changes in fruit resources. Studies focusing on seed dispersal generally overlook the relevance of the temporal changes of crops and animal densities (although with some exceptions). Therefore, we urgently need to understand how changes in the temporal abundance of both plants and dispersers alter the outcome of mutualistic seed dispersal interactions. The pressure for this understanding is given by current scenarios of the Anthropocene, because the timing of the life cycles of the interacting partners can be changed, notably as a consequence of climate change. This phenological uncoupling is one of the most frequent reasons for the presence of forbidden links in ecological networks, i.e. interactions that remain unobserved because of biological constraints (and not because of limited sampling effort). There is ubiquitous evidence that climate change has affected the timing of life cycles in organisms. However, we are much more ignorant on how phenological changes will in turn affect interactions among species by means of disruptions in activity overlap (i.e., increased rates of forbidden links). This symposium aims at filling this gap by presenting novel and outstanding research.

HOW A NETWORK APPROACH ADVANCES OUR UNDERSTANDING ON SEED DISPERSAL INTERACTIONS IN A CHANGING WORLD

ISABEL DONOSO, ANNA TRAVESET
04 MARCH 2020

Over recent decades, the analysis of interaction networks has gained in popularity among ecologists since they provide a clear and detailed picture of how species coexist and influence one another from a community-wide perspective. Ecological networks thus provide both the mechanistic approach and the holistic view which are essential to understanding ecological processes and the consequences of anthropogenic impacts in the organisation and functioning of whole ecological communities. In recent years, significant advances took place regarding the topology and structure of seed-dispersal interaction networks, as well as the responses of individual species or species interactions to global change. Yet, the question of how human impacts on species interactions (e.g. as a consequence of species extinction or invasion) might translate into changes on whole ecosystem functions such as seed dispersal provided by frugivorous animals remains underexplored. Network ecology is a very dynamic research field, which offers a valuable tool to assess structural and functional changes from a community viewpoint, as well as to evaluate the effectiveness of restoration plans of human-disturbed ecosystems. Therefore, in this symposium we aim to bring together researchers interested in ecological networks in order to offer an overview of new perspectives, current approaches and challenges in the study of seed dispersal interaction networks under global change. We hope that this session will help improve the understanding and management of ecological communities in a changing world, including effective conservation plans to guarantee ecosystem persistence and functioning.

TWO SIDES OF THE COIN: DEFAUNATION AND REWILDING EFFECTS ON FRUGIVORY AND SEED DISPERSAL PROCESSES

CAROLINA BELLO, NACHO VILLAR, JENS SVENNING, ANA BENÍTEZ-LÓPEZ
05 MARCH 2020

Extinction of animals from ecosystems leads to a collapse of assisted seed dispersal, but adequate reintroductions of animals can partially reverse this critical ecosystem process. With the current biodiversity crisis and accelerated rate of species loss, many forests, savannahs, grasslands and deserts are now becoming defaunated ecosystems. With the loss of animals, cascade effects trigger over other populations and ecosystem processes, such as frugivory and seed dispersal. Frugivory and seed dispersal are key processes for maintaining plant and animal diversity. For example, in tropical forests 70 to 94% of the woody plant species produce fleshy fruits that are consumed and dispersed by animals. Moreover, tropical animals depend on fruits as a food source at some points during their lifetime span, with intensive frugivory or during critical periods. Yet, mounting evidence suggests that defaunation can affect the frugivory and seed dispersal functionality. Specifically, the loss or functional extinction of frugivores can lead to a decline in seed removal rates, dispersal distances, and survival probability. This may induce rapid evolutionary changes in seed size, disrupt gene flow, and ultimately, affect other ecosystem services such as carbon storage. To restore these missing functions, a novel ecological restoration technique has emerged, referred to as Rewilding. Rewilding aims to restore top-down trophic interactions and reverse defaunation and its cascading effects on ecosystem processes by re-introducing wildlife species that went locally extinct in the past or species with similar functional roles. This symposium presents a series of forward-looking talks to update the current knowledge of defaunation effects on frugivory and seed dispersal processes and explore the effectiveness of Rewilding for restoring ecosystem processes. This

symposium would gather case studies showcasing the most recent advancements in our understanding of the ecological effects of defaunation, and on the potential of rewilding to restore frugivory and seed dispersal across different ecosystems. The symposium will introduce the audience to (1) the interlinkages between animal population declines, trophic interactions and impaired frugivory and seed dispersal, (2) to explore possible strategies to overcome the loss of key ecosystem processes through rewilding.

NON-NATIVE FRUGIVORES AND SEED DISPERSAL IN NOVEL ECOSYSTEMS OF THE ANTHROPOCENE

ANN MARIE GAWEL
05 MARCH 2020

Although conservation has long focused on maintaining intact or historical ecosystems and combating species introductions, the traditionally negative view of non-native species has been repeatedly called into question. Indeed, non-native species have undeniably been linked to native species extinctions, decreases in biodiversity, and drastic alterations of ecosystems in many systems. However, in many systems, especially where local species have been diminished or gone extinct, we see non-native species restoring important functions such as seed dispersal. Further, native species could do harm in the context of novel ecosystems with highly altered species compositions by promoting harmful species or by negatively affecting rare native species through altered ecological processes. Discerning these interactions is an important step to conservation planning in the Anthropocene. Reflecting the theme "Seed dispersal in the Anthropocene," our symposium is focused on interactions involving non-native species in novel ecosystems. Our talks will highlight both non-native frugivores and the dispersal of non-native plant species with an emphasis on the resulting implications for conservation.

APPLICATIONS OF FRUGIVORY AND SEED DISPERSAL FOR ECOLOGICAL RESTORATION

ANAND OSURI, DIVYA MUDAPPA, T R SHANKAR RAMAN
06 MARCH 2020

Ecological restoration, aimed at overcoming barriers to natural recovery in degraded ecosystems, has emerged as an important strategy for reversing global losses of biodiversity and ecosystem functions. In ecosystems comprising predominantly animal-dispersed plant species, restoration can interact with frugivory and seed dispersal (FSD) in a number of interesting and important ways. In theory, animal frugivores can catalyze restoration by dispersing seeds into degraded habitats. However, the contribution of frugivory and other biotic processes to vegetation recovery also depends on a range of factors including landscape context (e.g., patch isolation), disturbance (e.g., hunting), and restoration goal and strategy (e.g., site or type of tree planting). Our symposium aims to bring together research from a variety of ecosystems to explore three broad themes at the intersection of anthropogenic disturbance, restoration, and FSD. First, what are the impacts of anthropogenic disturbances such as fragmentation and habitat conversion on frugivore communities, and how do these impacts constrain natural vegetation recovery in disturbed ecosystems? Second, what are the effects of restoration on animal-mediated processes such as seed dispersal, herbivory and plant regeneration? Finally, how do these effects vary across different strategies for restoration - e.g., passive vs. active restoration? One of our main motivations for organizing this symposium is to facilitate interactions and exchange of ideas between researchers working within the three broad topics listed above, as a step towards facilitating more cross-cutting research on the linkages and feedbacks that characterize anthropogenic disturbance-restoration-FSD relationships. We hope to stimulate researchers in the field of FSD to think about how their own work relates to, and can inform, forest conservation and restoration in the Anthropocene.



ABSTRACTS

S Potential of inter-island seed dispersal by Japanese Wood-Pigeon in relation to their movement pattern and fruiting phenology

Haruko Ando, Yuka, Mori & Nozomu J Sato

Long-distance seed dispersal among islands is essential for vegetation development in oceanic island ecosystems. Pigeons possibly contribute to long-distance seed dispersal on oceanic islands due to their large body size, strong flying capacity, and relatively long gut-passage time. Some of the island pigeons are known to move among islands, but their movement pattern and contribution to inter-island seed dispersal have not been well-studied. We aimed to estimate the relationship between pigeons' inter-island movement pattern and fruiting phenology and their potential for inter-island seed dispersal, targeting Japanese Wood-Pigeon *Columba janthina*. In Hachijojima and Hachijokojima in the Izu Island chain, we monitored pigeon populations, fruiting phenology, and their seasonal movement pattern among the islands once a month from June 2018 to May 2019. We also collected faecal samples to detect seeds that can be dispersed by pigeons. We found large numbers of Japanese Wood-Pigeons moving between Hachijojima and Hachijokojima approximately 4 km apart within a day. The pigeon population and number of individuals moving between islands fluctuated dramatically among seasons (0 - >5,000), positively correlated with fruit abundance of each island, which may be related to their breeding. Although Japanese Wood-Pigeons were thought to be seed predators, some of the plant seeds with small diameter (< 1.5 mm) were detected from pigeon faeces and phenologies of these plants were similar to pigeon movement patterns. This study indicated that highly mobile seed predators such as Japanese Wood-Pigeons may contribute to inter-island seed dispersal on oceanic islands. Seed size and phenological coordination with pigeons' movement may be important factors for plants to be dispersed by pigeons.

P Current status of frugivory and seed dispersal research in Nepal

Balram Awasthi

The present review targets the status of frugivore and seed dispersal research in Nepal. Frugivores play a huge role in structuring and restoring terrestrial ecosystems and provide important ecosystem services. The importance of fleshy fruit in the diet of mammals, birds and reptiles and their role as seed dispersers has received comprehensive attention by researchers worldwide. I review the studies carried out on frugivory and seed dispersal in Nepal, to determine future research requirements of this understudied region. Nepal has a complex topography and covers a large altitudinal variation from the Terai plains (60 m asl) to the high mountains (Mount Everest, 8848 m). Hence, despite its small size, Nepal harbors over three percent and one percent of the world's known flora and fauna, with about 49 species of mammals and 101 species of birds that are fruit-eaters. Nepal is also one of the very few areas in Asia where two megafauna, the elephant and the rhinoceros co-exist. Only two seed dispersal studies on megafauna have been conducted in Nepal, but no information on seed dispersal by birds is available, despite several important frugivorous taxa being present. Rhinoceros have been reported to be important seed dispersers of a variety of large-seeded species—in particular *Trewia nudiflora*, with elephants reported to consume and disperse different species to that reported for rhinoceros. There is a general lack of systematic research on frugivores and seed dispersers in Nepal. It is timely to promote research, awareness and conservation intervention for Nepal's frugivores and improve our understanding of their role in seed dispersal. This review will be used to promote the importance of these animals to government agencies, academic institutions and local researchers to increase research and conservation activities in the field of frugivory and their role in seed dispersal.

S Complementarity of seed dispersal mechanisms mediated by ungulates

Christophe Baltzinger, Sorour Karimi & Ushma Shukla

Up until now, zoochory-based interaction networks largely focused on seeds produced by the parent plant and dispersed by endozoochory. Relatively few studies have dealt with fur-epizoochory, and even fewer with these two dispersal mechanisms together. Here, we specifically focused on plants co-dispersed by ungulates, assuming that this could generate complex dispersal kernels. We had three objectives: 1. to discuss complementarity for ungulate-mediated dispersal mechanisms, 2. to provide a first assessment based on the diversity of plants dispersed, and 3. to test it using two datasets with red deer (*Cervus elaphus*) as the dispersal vector. We performed a systematic literature review to gather cases where both endozoochory and fur-epizoochory were studied for an ungulate. We then considered the percentage of plants (native and alien) dispersed by both mechanisms. We checked if specific ungulate traits (feeding regime, fur characteristics) could help explain the observed patterns. We finally took advantage of a recently published dataset and used species accumulation curves to test if endozoochory and fur-epizoochory samples collected on the same individuals were complementary. We retrieved 21 cases that studied native and domestic ungulates. Two thirds of cases highlight a higher proportion of species dispersed by endozoochory only, in comparison with fur-epizoochory only or both. The overlap of plant species dispersed both by endozoochory and fur-epizoochory was higher for grass and roughage eaters, followed by omnivores, intermediate mixed feeders and concentrate selectors. Both native and alien plants were considered. We further showed that species accumulation curves taking into account plants dispersed by endozoochory and fur-epizoochory grew faster than curves for endozoochory or fur-epizoochory separately, thus validating our taxonomic complementarity hypothesis. If we rely on dispersal services provided by ungulates for the restoration of degraded habitats, we need to keep in mind that they disperse numerous native and alien plants by endozoochory and fur-epizoochory.

S Advancing an interdisciplinary framework to study seed dispersal ecology

Noelle Beckman

Although dispersal is generally viewed as a crucial determinant for the fitness of any organism, our understanding of its role in the persistence and spread of plant populations remains incomplete. Generalizing and predicting dispersal processes are challenging due to context dependence of seed dispersal, environmental heterogeneity, and interdependent processes occurring over multiple spatial and temporal scales. Current population models often use simple phenomenological descriptions of dispersal processes, limiting their ability to examine the role of population persistence and spread, especially under global change. To move seed dispersal ecology forward, we need to evaluate the impact of any single seed dispersal event within the full spatial and temporal context of a plant's life history and environmental variability that ultimately influences a population's ability to persist and spread. In this perspective, we provide guidance on integrating empirical and theoretical approaches that account for the context-dependency of seed dispersal to improve our ability to generalize and predict the consequences of dispersal, and its anthropogenic alteration, across systems. We synthesize suitable theoretical frameworks for this work and discuss concepts, approaches, and the available data from diverse subdisciplines to help operationalize concepts, highlight recent breakthroughs across research areas, and discuss ongoing challenges and open questions. We address knowledge gaps in the movement ecology of seeds and the integration of dispersal and demography that could benefit from such a synthesis. With an interdisciplinary perspective, we will be able to better understand how global change will impact seed dispersal processes, and potential cascading effects on plant population persistence, spread, and biodiversity.

S Rewilding defaunated Atlantic Forests with tortoises to restore lost seed dispersal functions
Carolina Bello, Thadeu Sobral-Souza, Laís Lautenschlager, Thais Queiroz Morcatty, Dennis Hansen & Mauro Galetti

The extinction of frugivores has been considered one of the main drivers of disruption of important ecological processes, such as seed dispersal. Many defaunated forests are too small to restore function by reintroducing large frugivores such as tapirs or Ateline monkeys, and the long-term fate of large-seeded plants in these areas is uncertain. However, such small fragments still host many species and play relevant ecosystem services. Here, we explore the use of two tortoise species, the Red-footed Tortoise *Chelonoidis carbonarius* and the Yellow-footed Tortoise *Chelonoidis denticulata*, as ecological substitutes for locally extinct large seed dispersers in small forest patches in the Brazilian Atlantic Forest. We employed prior knowledge on the known occurrences of *Chelonoidis* species and used ecological niche modeling (ENM) to identify forest patches for tortoise rewilding. Based on habitat suitability, food availability and conservation co-benefits, we further refined our analysis and identified that the more suitable areas for tortoise reintroduction are forest patches of northern Atlantic Forest, areas with high defaunation intensity. Giant tortoises have been used to restore lost ecological services in island ecosystems. We argue that reintroducing relatively smaller tortoises is an easy-to-use/control conservation measure that could be employed to partially substitute the seed dispersal services of extinct large disperser species, mitigating the negative cascading effects of defaunation on reducing plant diversity.

P Effect of local disturbance on frugivorous birds in fragmented tropical rainforests
Pooja Bishaya & Narayan Sharma

Anthropogenic habitat disturbances such as forest fragmentation is a major threat to tropical forests. Fragmentation leads to a change in the structure and dynamics of remnant populations, often having negative ecological consequences, which can affect ecosystem functioning. Seed dispersal is an essential process in ecosystems through its influences on plant demography and association with the diversity of frugivorous birds. Thus, the proposed study is to determine the effect of habitat fragmentation on frugivorous bird communities in tropical lowland rainforest fragments of the upper Brahmaputra valley, north eastern India. The study will be conducted in 18 forest fragments with varying degrees of anthropogenic disturbance. The local disturbances that will be included for the study are forest cover, tree density, logging density and the encounter rates of cattle and humans. The hypotheses addressed are that, with the increase in disturbance gradient, diversity of frugivores will decrease. This is because most large frugivore species are likely to be dependent on patchily distributed trees that fruit at different times, and the lowered vegetation diversity in small fragments may not support them. Also, earlier research similar to the proposed study observed a negative relation between disturbance and frugivore bird diversity. Similarly, forest cover loss showed a negative relation with fruit consumption and hence seed dispersal. Therefore, by understanding the ecological consequences of habitat fragmentation, more effective conservation policy for these remnant forest patches can be implemented for the conservation of biodiversity.

T Dispersal of invasive *Lantana camara* by native bird species in KwaZulu-Natal, South Africa Nasiphi Bitani & Colleen T. Downs

Alien invasive plant species are a major problem globally, threatening ecosystem functioning and biodiversity. Their spread is facilitated by native bird species through mutualistic relationships. In South Africa, there is limited information on the role of native birds in seed dispersal of fleshy-fruited alien invasive species. For effective management of invasive plant species, it is important to understand processes that contribute to their successful spread. In this study, the role of native bird species in the dispersal of a highly invasive shrub *Lantana camara* was investigated in KwaZulu-Natal, South Africa. Bird species visiting fruiting *L. camara* were observed and the maximum potential dispersal distances were estimated. A total of 56 bird species were observed visiting *L. camara* with only 28 species consuming the fruit. Visitation frequencies were significantly higher for small- and medium-sized frugivorous species. The Common Bulbul *Pycnonotus barbatus* was the most observed frugivorous bird species visiting and was likely the main disperser of *L. camara*. Interestingly, two non-frugivorous birds, the White-bellied Sunbird *Cinnyris talatala* and the White-browed Scrub Robin *Cercotrichas leucophrys* showed relatively high visitation frequencies to *L. camara*. Of the 28 species that ingested fruit, potential seed dispersal distances ranged from 9 to 45 km. Short potential seed dispersal distances were more common than long dispersal distances that were limited by relatively rare frugivores. Level of frugivory and body size were the main traits that influenced dispersal effectiveness. Our results suggest that native bird species are important seed dispersers of invasive *L. camara*.

O Orangutan seed dispersal in Gunung Palung National Park, Borneo, Indonesia: dispersal quantity, germination rates, gut transit times, and dispersal distances Andrea Blackburn, Tri Wahyu Susanto & Cheryl D. Knott

Orangutans are large-bodied frugivores predicted to be important seed dispersers, however little is known about their seed dispersal effectiveness. To understand wild Bornean Orangutan (*Pongo pygmaeus wurmbii*) seed dispersal effectiveness, we measured the quantity of seeds dispersed, and we considered the quality of dispersal by measuring germination rates of gut-passed and control seeds, gut transit times, and dispersal distances. Research was conducted in Gunung Palung National Park, Borneo, Indonesia (August 2018 to August 2019). We systematically collected orangutan faecal samples, made observations on feeding behavior, and got GPS tracks during consecutive full-day focal follows. We sieved 549 faecal samples collected from 36 orangutans to count and identify seeds (> 2 mm). Out of the faecal samples collected, 413 (75.2%) contained seeds. A total of 24 genera were dispersed via endozoochory. Orangutan faecal samples contained a mean of 1.17 genera (range 0-7). Germination experiments were conducted with orangutan defecated seeds and seeds from fruit. A significantly higher percent of orangutan defecated seeds germinated for 5 out of 6 genera than control seeds with pulp ($P < 0.01$). A significantly higher percentage of orangutan defecated seeds germinated for 3 out of 6 genera compared to control seeds without pulp ($P < 0.01$). Gut transit times in wild orangutans ranged from 39.5 to 87 hours ($N = 6$). Finally, we modeled seed dispersal distances using orangutan movement tracks ($N = 30$) with gut passage durations of 45 and 60 hours. Gut retention times of 45 hours resulted in a mean dispersal distance of 507 ± 123 m (range 69-1341), and 60 hours resulted in a mean distance of 592 ± 115 m (range 83-1260). We conclude orangutans are effective seed dispersers with similar efficacy to other great apes. Orangutans disperse a wide variety of genera over medium to long distances and gut passed seeds germinate at higher rates compared with controls.

Maximization of energy or nutrient balancing: the interplay between fruit chemical content and foraging behaviour in fruit-eating birds

Pedro G. Blendinger, Irene M. A. Bender, Silvia Lomáscolo, Julieta Magro, Mariano Ordano, M. Gabriela Núñez Montellano, Andrés F. Ramírez-Mejía, Tobias N. Rojas, Román A. Ruggera & Mariana Valoy

The fruit diet of frugivores is driven by foraging strategies of energy maximization or nutrient balancing. However, frugivores face a changing fruit market when they make foraging decisions. It is well known that the amount of available fruits and phenotypic trait matching impose filters on the fruit diet, but less is known about the role of foraging decisions of the fruit chemical content. The differences between fruit species in pulp quantity and chemical quality can interact with behavioural, morphological and physiological traits of the consumers, determining the contribution of the fruit species to the provision of nutrients and energy. We use extensive field and laboratory data and modelling to explore whether a fruit-based diet can provide energy and nutrients necessary for frugivores, as well as its variation between functional types of frugivores. Using the Resource Provisioning Effectiveness (RPE) framework we investigate the effectiveness of consumed fruit species to provide daily requirements of energy to Andean birds, and compare them with the composition of field diets. Similarly, we use Nutritional Geometry (NG) framework to assess the adjustment of field fruit diets to a theoretical diet balanced in macronutrients. We use diet data of ca. 35 bird species from different sites and seasons, chemical data of ca. 40 species of fruits; we model the daily ingestion rate of each fruit species for each frugivore, and estimate their energy assimilation and macronutrient balancing in the diets. Then, we assess how fruit RPEs and balances depend on the bird's fruit handling behaviour, body size and specialization, and the adjustment of the diet to energy maximization (in terms of RPE) and nutrient balancing (in terms of NG) strategies. We provide valuable information on how fruit chemical composition interacts with the ability of the frugivores to acquire pulp, determining the foraging decisions and the composition of the fruit diet.

Climate warming disrupts mast seeding and its fitness benefits in European beech

Michał Bogdziewicz, Dave Kelly, Peter A. Thomas, Jonathan G.A. Lageard & Andrew Hackett-Pain

Large synchronous year to year variation in seed production (mast seeding) is a common reproductive strategy in plants that could be sensitive to climate change because it relies on synchronizing weather cues. Using a 39-year dataset of seed production, seed predation, and pollination success of 139 European beech trees, we showed that climate warming increased the mean seed production of individual trees, but decreased synchrony among individuals, resulting in lower population-level interannual variability of reproduction. This weakening of mast seeding eroded benefits to the plants from predator satiation and wind pollination. Consequently, the higher reproductive effort of plants in a warmer world resulted in decreased pollination and higher losses to seed predators. This shows that a simple apparent benefit of warming unravels because of complex ecological interactions. These changes in masting patterns will have profound implications for the future functioning of mast seeding trees in a changing climate.

O Modifications of the rainforest frugivore community are associated with reduced seed removal at the community level

Olivier Boissier, François Feer, Pierre-Yves Henry & Pierre-Michel Forget

Tropical rainforests worldwide are under increasing pressure from human activities, which are altering key ecosystem processes such as seed dispersal. However, while the direct impact of anthropogenic disturbance on animal communities has been well studied, the consequences of such defaunation for seed dispersal remains chiefly understood at the plant species level. We asked whether communities of endozoochorous tree species had altered seed removal in forests affected by hunting and logging and if this could be related to modifications of the frugivore community. At two contrasting forest sites in French Guiana, Nouragues (protected) and Montagne de Kaw (hunted and partly logged), we focused on four families of animal-dispersed trees (Sapotaceae, Myristicaceae, Burseraceae and Fabaceae) which represent 88% of all endozoochorous trees which were fruiting at the time and location of the study. We assessed the abundance of the seed dispersers and predators of these four focal families by conducting diurnal distance sampling along line transects. In parallel, we estimated seed removal rates from fruit and seed counts conducted in one-square-meter quadrats placed on the ground beneath fruiting trees. Densities of several key seed dispersers such as large-bodied primates were greatly reduced at Montagne de Kaw, and community-level seed removal rates dropped from 77% at Nouragues to 47% at Montagne de Kaw. This confirms that the loss of frugivores associated with human disturbance impacts seed removal at the community level. In contrast to Sapotaceae, whose seeds are dispersed by mammals only, weaker declines in seed removal for Burseraceae and Myristicaceae suggest that some compensation may occur for these bird- and mammal-dispersed families, possibly because of the high abundance of toucans at the disturbed site. The defaunation process currently occurring across many tropical forests could dramatically reduce the diversity of entire communities of animal-dispersed trees through seed removal limitation.

T The Iberian Lynx as a modeler of seed dispersal through trophic cascades

Tamara Burgos, Emilio Virgós, Javier Seoane, José María Fedriani, Gema Escribano-Ávila, Inmaculada Cancio & Javier Rodríguez-Siles

Apex predators play a key role in ecosystems, and their conservation could be a main tool to maintain and improve global biodiversity. They are part of numerous food webs affecting lower levels through trophic cascades. Recent reintroductions and restorations of large predators around the world offer a unique opportunity to learn about the effects of this group in the dynamics of ecosystems. We studied the indirect top-down effect of an endangered top predator, the Iberian Lynx, on the quantity and quality of seed dispersal by smaller frugivorous carnivores. The study was carried out in Sierra Morena Mountains, in south Spain, by comparing locations with the territorial presence of Iberian Lynx with sites without lynxes. We collected scats of frugivorous mesocarnivores along linear transects in two types of habitats which represent different levels of perceived predation risk. We performed a dietary analysis from 774 collected scats, counting and identifying all seeds consumed to species level. We found the Iberian Lynx affects the scent-marking behaviour of the mesocarnivores and exerts a top-down regulation on seed dispersal processes of fleshy fruits. The number of fleshy-fruits that had seeds dispersed by carnivores was significantly reduced in the presence of lynx because of a lower rate of scent-marking with faeces. The Red Fox (*Vulpes vulpes*) avoided scent-marking in exposed habitats when lynx were present, decreasing the number of seeds mobilized to open habitats due to an increase in perceived predation risk. In the case of the Stone Marten (*Martes foina*), we found a significant decrease in the number of scats and seeds dispersed in the presence of lynx, mobilizing the seeds to forest habitats regardless of the presence of the feline. A lower abundance of frugivorous carnivores linked to a behavioral adaptation to avoid agonistic encounters with a superpredator could have long-term effects on landscape structure and plant communities.

Fruit crop size and diversity of visiting birds enhance seed dispersal effectiveness

Mariana Lopes Campagnoli & Alexander Vicente Christianini

The fruit crop size hypothesis states that plants producing larger crops are likely to attract a greater number and diversity of frugivores, which could lead to positive outcomes for seed dispersal effectiveness (SDE) received by the plants. SDE can be estimated from components of quantity, which account for the number of seeds dispersed away, and quality, which accounts for the likelihood of seed recruitment. Highly productive plants may be better to attract a greater diversity of visitors, including high quality dispersers, i.e., species that remove a great number of seeds without harming them. Nevertheless, large crops may also attract opportunistic species that provide low quality dispersal. We evaluated how fruit crop size affected the diversity (Shannon index) of visitors, the frequency of visits by high and low quality dispersers, and the SDE received. We estimated crop size and performed focal observations for birds visiting each of ten sugar-rich *Miconia rubiginosa* and lipid-rich *Xylopia aromatica* during a fruiting season in 2019, in a savanna in southeastern Brazil. We found 19 bird species feeding on the plants, maximum richness per plant being nine species and minimum one species. Crop size had positive effects on visitor diversity and SDE for *M. rubiginosa*, but not for *X. aromatica*. Larger crops were more likely to attract high quality dispersers in *M. rubiginosa*, but no such pattern was found in *X. aromatica*. However, diversity of visitors had a positive effect on SDE in both species irrespective of crop size, indicating that trees attracting a more diverse assemblage also attain higher SDE. For example, attracting less common species could be important for the dispersal of seeds that would not be dispersed otherwise due to satiation of most common species. Thus, our study indicates a positive link between biodiversity and a critical ecosystem service for plant community diversity and regeneration.

Filling gaps in the model of *Prosopis flexuosa* seed dispersal effectiveness: the quality of treatment in the digestive tract of domestic and wild animals.

Claudia M. Campos, L. Ramos, S. Campagna, N. Manrique, V. Egea, F. Cappa & M. Cona

The fruits of *Prosopis flexuosa* are indehiscent pods palatable to endozoochorous dispersers. Because species impose different costs on seeds due to mastication and exposure to digestive enzymes, the aim of this study was to analyse the quality of treatments following seed ingestion by domestic (cow, goat, horse) and wild (*Chelonoidis chilensis*, *Dolichotis patagonum*, *Lama guanicoe*, *Lycalopex gymnocercus*, *Rhea americana*) animals. Using a comparative experimental approach on captive animals, we quantified retention times, seed recovery, and the impact of gut passage on seed viability and germination. Each individual was isolated in a cleaned enclosure and then fed with a known number of seeds. We collected their faeces daily and crushed them manually to obtain seeds for the germination experiment and viability test. Retention time for domestic animals was between 2-5 days, and we recovered 41% of seeds ingested by horses (N = 4 individuals; 35% of recovered seeds were viable; 10% of seeds germinated in 30 days), 3% by cows (N = 4; 53% viable seeds; 8% germinated seeds) and 2% by goats (N = 4; 34% viable seeds; 16% germinated seeds). The retention time of seeds for wild animals ranged from 4 to 33 days. We recovered 81% of seeds ingested by *R. americana* (N = 2; 43% viable seeds; 7% germinated seeds), 65% by *D. patagonum* (N = 5; 50% viable seeds; 30% germinated seeds), 64% by *L. gymnocercus* (N = 3; 37% viable seeds; 3% germinated seeds), 53% by *C. chilensis* (N = 6; 70% viable seeds; 41% germinated seeds), and 25% by *L. guanicoe* (N = 2; 40% viable seeds; 35% germinated seeds). Our results showed that the quality of seed treatments varied among species due to the effect of morphological and physiological traits of animal taxa. We found that knowing the initial number of ingested seeds improves the assessment of seed dispersal quality, because of the large variation in the proportion of seeds recovered from the faeces of different species.

S Understanding frugivory and seed dispersal as an informatic process

Tomás A. Carlo

A significant fraction of plants have evolved edible structures - fruits - to lure unwary animals into the business of dispersing their seeds. During the moment seeds ride inside the body of a frugivore, plants quite literally “move like animals”. Animal movements are characteristically non-random, which have the important property of making seed destinations also non-random. The success of this mutualistic process has been tremendous and plants dispersed by frugivores are dominant or important in many terrestrial ecosystems of the planet, especially so in the tropics where terrestrial diversity reaches its highest levels. Frugivory and seed dispersal mutualisms (FSD) are thus an integral part of the regeneration, structure, and functioning of diverse communities as we know them. Here I examine some key properties of FSD processes, emphasizing that frugivore-plant interactions constitute an information transfer process that organizes the structure of communities in several ways. This model follows Margalef’s vision—more than 70 years ago—that the key organizational feature of organismal communities are their spatial and temporal relationships. Understanding FSD as an informatic process can advance our conceptual understanding of functionally integrated communities and their conservation.

P Threatened Hyacinth and Lear’s macaws are legitimate seed dispersers of plants with megafaunal fruits.

Martina Carrete, Fernando Hiraldo, Erica Pacifico, José A. Díaz-Luque, Francisco, V. Dénes, Fernanda M. Fontoura, Neiva Guedes & Guillermo Blanco

Dispersal of many large-fruited (> 4 cm diameter) plants is thought to have been handicapped after the extinction of megafauna in the late Pleistocene and the recent defaunation of large mammals, with free-ranging livestock partially supplying the dispersal services previously provided by those species. We recorded seed dispersal behavior of two large macaws (*Anodorhynchus hyacinthinus* and *A. leari*) in three Neotropical biomes, totaling > 1700 dispersal events from 18 plant species, most (98%) corresponding to six large-fruited palms. Dispersal rates varied among palm species (5-100%). Fruits were moved to perches at varying distances (mean 17-450 m, maximum 1620 m). Macaws also moved nuts after regurgitation by livestock, in an unusual case of tertiary dispersal, to distant perches. A high proportion (11-75%) of dispersed palm nuts was found undamaged under perches, and palm recruitment was confirmed under 6-73% of the perches. Our results show that even large macaws that mostly feed on palm seeds act as legitimate, long-distance dispersers, and challenge the prevailing view that dispersal of large-fruited plants was compromised after megafauna extinction. The large range contraction of these threatened macaws, however, has meant that these mutualistic plant-animal interactions are functionally extinct over large surface areas at a continental scale.

S **Functional changes in assemblages of avian frugivores following extinction and invasion** *Samuel B. Case & Corey E. Tarwater*

Extinction and invasion can alter ecological processes owing to loss or gain of species roles. In vertebrate-dependent seed dispersal, mutualisms between frugivores and fruiting plants depend, in part, on matching of functional traits. Most native frugivores of the Hawaiian Islands have gone extinct since human arrival, but many frugivorous birds have been introduced. Despite high species turnover, impacts of frugivore extinction and invasion on seed dispersal remain unclear. We investigated how frugivore traits differ between historic and modern communities of the Hawaiian Islands. We examined gape width, body mass, and wing shape, all of which impact frugivory and/or dispersal distance. We also tested how gape width and body mass shifted within foraging guilds (ground versus arboreal) to distinguish potential impacts on low versus high forest strata. Compared to historic frugivores, the modern assemblage is smaller in gape width and body mass in both ground and arboreal guilds. Wing shape did not significantly change between assemblages. From the results, we postulate that the changes in the frugivore community have altered seed dispersal processes by reducing the size of seeds consumed, frugivory rates per animal, and seed dispersal distances. Consequently, dispersal limitation may threaten Hawaiian plant communities, with larger-seeded plants at greatest risk of extinction.

O **Plants alter some fruit traits under different simulated frugivory rates** *Brittany Cavazos & Haldre Rogers*

While it has been long known that plants can respond to abiotic factors like light and precipitation, and more recently it has been shown that they can respond to biotic factors like herbivore and pollinator visitation, it is unclear whether plants can respond to changes in their frugivore community. Given that fruits are costly to create and frugivores may be unreliable or inconsistent in most communities, we hypothesize that fleshy-fruited plants should respond to frugivore activity. Specifically, we hypothesized that they could shift their resource allocation towards traits a frugivore may find more attractive. To test whether fruit traits respond to frugivory, we set up a greenhouse experiment with a wild tomato species, *Solanum pimpinellifolium*, using replicate genotypes and simulating low, medium, and high frugivore visitation. We measured fruit size, seed size, seed number, flesh:seed ratio, and ripening time and tested for differences in these traits across time under different removal treatments. We found no effect of fruit removal on seed size, seed number per fruit, or ripening time. However, we found that with decreased frugivory, fruit size and mass were significantly smaller over time and the effect size varied based on the tomato source population. This is consistent with the hypothesis that some plants are reducing investments in fruits when not being dispersed and this varies geographically. While we do not know the natural rates of frugivory on these plants in these locations, this could indicate high plasticity under different natural levels of fruit removal. These results imply that some fleshy fruited plants are capable of rapidly responding to changes in their frugivore communities in ways that could increase their overall fitness.

O **Consequences of intraspecific variation in seed size: do small seeds enhance the survival of large ones?** *Paulina Celebias, Michał Bogdziewicz & Rafał Zwolak*

Seed size may vary substantially within a single plant community. Availability of resources, characteristics of microhabitat, and herbivore damage of the mother plant were so far listed as possible drivers of that variation. We tested a novel hypothesis that the production of different size seeds by a plant may be a strategy to decrease predation by granivores. We conducted a seed removal experiment in the

stands of *Quercus petraea* in Poland. We presented acorns on Petri dishes in two configurations: large acorns alone (mean = 31.06 and SD = 1.54), and large acorns mixed with the smallest ones (mean = 22.50 and SD = 1.25). The Petri dishes were monitored for a month which allowed us to determine their survival. We found that large acorns of *Q. petraea* have a substantially higher survival rate in the presence of the small ones. During the research period, scatter-hoarding animals collected seeds primarily from dishes with big seeds alone, mostly ignoring mixed treatments. The presence of small acorns can enhance the persistence of the large ones in the environment. This implies that large intraspecific variation in seed size can be a strategy to avoid seed predation by granivores. Currently, we follow up on this experiment by conducting a study where we examine the influence of variation in acorn size on post-removal acorn fate (dispersal vs. predation).

P The Picazuro Pigeon: a seed predator or an unexpected disperser?

Cristiane Tibério Checon, Mariana Franciscão Costa & Wesley Rodrigues Silva

The Picazuro Pigeon (*Patagioenas picazuro*, Columbidae) is a species associated with open and semi-open habitats in South America. In the last 50 years, it expanded its area of distribution, mainly due to deforestation, fragmentation, and urbanization, now occupying many urban habitats that retain minimal tree coverage. This species, formerly referred to as granivorous, began to be recorded as frugivorous or both in recent articles from this century. The newly acquired fruit diet and the ability to survive in open areas where most large frugivores became rare or absent, can turn this species into an important seed disperser in disturbed habitats. In an attempt to evaluate the frugivorous diet of this pigeon and verify its role as a seed disperser, we undertook a literature review, collected faecal samples scattered below trees at the University of Campinas' campus from September 2018 to January 2019, and also offered seeds to individuals kept in captivity from January to July 2019. Seeds obtained in the campus and from captivity were both used in germination tests in a greenhouse. Overall, 27 species of native and exotic fruits are eaten by this pigeon. The most common seed species found in faecal samples were *Solanum americanum*, *Solanum granuloso-leprosum* (germination rate: 63% and 28% respectively), *Cordia myxa*, and *Citharexylum myrianthum* (both did not germinate). These were found mostly intact, with very few being damaged or destroyed. Most (95%) of *Cecropia pachystachya* seeds retrieved from captivity were intact and their germination rate was 19%, in contrast to 13% germination rate of the control group. Our study highlights that *Patagioenas picazuro* can be considered an eventual frugivore, capable of dispersing exotic and native seeds up to 10 mm in diameter, making it an important seed disperser in disturbed habitats of Southwest and South Brazil.

O Temporal variation in the effectiveness of seed dispersal in a Neotropical savanna

Alexander V. Christianini & Mariana Lopes Campagnoli

Seed dispersal effectiveness (SDE) can be estimated based on quantity and quality components of the dispersal process. Quantity accounts for the number of seeds dispersed away, while quality accounts for the likelihood of recruitment of dispersed seeds. In spite of an increase in available estimates of SDE, we still know little about how effectiveness varies with time. Since frugivore assemblage composition and abundance, as well as plant investment in crop sizes and resource abundance may vary largely between years, it is likely that SDE is also quite dynamic in time. We used focal observations and field experiments to investigate the temporal variation in SDE in a Cerrado savanna from southeastern Brazil. We obtained data for 26 species of birds and 34 of ants interacting with the sugar-rich diaspores of *Miconia rubiginosa* and the lipid-rich *Xylopia aromatica* in 2004, 2005, and 2019 fruiting seasons. We used interaction frequency and seed treatment as proxies for quantity and quality. Contributions to SDE

varied widely within and among species of bird and ant visitors between years, more in quantitative than in qualitative ways. Although the assemblage of interacting species changed over the years, the central core of species (defined as those performing at least 10% of interactions) remained relatively more stable than rare species (those performing up to 5%). Plants producing larger crop sizes attracted a more diversified assemblage of visitors and attained a higher SDE than plants producing comparatively smaller crops. The conservative trait of the core assemblage of interacting species translated in a consistent contribution of birds and ants to plant regeneration between years in spite of changes in interactions with rare species. A stable core of visitors between years can increase the potential for coevolutionary convergence of traits among species on both sides of the interaction.

Bare-throated Bellbird ecology and rainforest tree diversity

Bernardo Clausi

Neotropical bellbirds comprise four species in the Cotingidae family. They are mostly geographically isolated, and all of them have an almost entirely frugivorous diet. The Bare-throated Bellbird is an endemic bird species of the Atlantic rainforest of southeastern South America. Despite its known frugivorous diet, not much is known about the interannual cycles in its diet or fruit preferences relative to availability. I documented what bellbirds eat throughout the year, the phenology of fruiting plants, and made observations of the male perches, under which seeds are deposited. In addition, opportunistic observations within the rainforest were gathered during the off season. Using these data, I assessed preferences and interannual variations within the bird diet. This dataset has been collected over 16 years—from 2003 to present. Important differences occur in the bellbird's diet among years and I find new plant species being added in each year of study. In total, more than 100 species have been recorded in the diet of the bellbirds at two study sites, (site 1, a lowland site where the birds sing actively from late June to January, and site 2, a highland site, mostly occupied from August to February. In June 2019, unprecedented singing occurred in the highland site, probably due to an especially abundant crop of *Prunus myrtifolia*. Dependence of these plant species on bellbirds for recruitment and seedling establishment varies. Male birds provided directed dispersal of their favoured species, such as *Myrcia*, *Eugenia*, *Ocotea*, and *Nectandra* (multiple species of each). I also documented very high rates of secondary seed dispersal and predation by rodents and other birds, after the seeds were deposited by the bellbirds.

The restoration of seed dispersal networks in Seychelles

Alba Costa, Ruben Heleno & Christopher Kaiser-Bunbury

Seed dispersal by vertebrates is a pivotal ecosystem function for the regeneration of plant-community structure and dynamics. The introduction of invasive alien plant species into a community can modify plant-disperser interactions and eventually lead to the disruption of seed dispersal services available to native plants. Therefore, the implementation of ecological restoration procedures based on removal of invasive plant species can be crucial for the conservation and recovery of plant-disperser interactions in a community. Ecological networks represent an excellent tool to monitor the restoration of ecological functions, such as seed-dispersal, at the community level. The aim of this study is to assess the effects of habitat restoration through invasive alien plant removal on seed dispersal interactions. We reconstructed seed dispersal interaction networks on eight inselberg plant communities (4 restored and 4 control sites) on the island of Mahé, Seychelles. Interaction networks were obtained by combining four different

sampling methods: camera traps, direct observations, macroscopic faecal analysis and DNA barcoding. As expected for an oceanic island, seed dispersal networks were relatively small, and their structure differed between restored and unrestored sites. The Seychelles Bulbul (*Hypsipetes crassirostris*) was by far the animal species that contributed most to the dispersal of seeds in terms of number of visits and plant species dispersed. Restored networks had a richer assembly of dispersers, which tended to disperse more seeds and more plant species than in unrestored sites. We conclude that eight years after weeding activities, the removal of invasive alien plant species from Seychelles inselbergs has positively affected seed-dispersal, likely contributing to a greater resilience of restored forests.

Interindividual variations in plant and fruit traits affect the structure of a plant-frugivore network

Ana Cristina Vara Crestani, Eliana Cazetta & Marco Aurelio Ribeiro de Mello

Frugivores select their food in a hierarchical way, from plants to individual fruits, to meet their nutritional requirements. According to the optimal diet theory, finding, handling, and digesting fruits is costly, thus plant species that increase attractiveness and reward are usually preferred by frugivores. The same should be expected for individual plants of the same population, which differ from one another in traits related to frugivore attraction. We tested the hypothesis that plant traits that increase attractiveness and reward to frugivores would be strongly selected by birds in a population of *Henriettea succosa* (Melastomataceae). Using focal observations we measured plant and fruit traits known to influence frugivore attraction and reward: plant height, fruit size, and fruit sugar content. In addition, we recorded bird behaviour during fruit consumption. We built a monolayer network and a multilayer network with four layers, one for each type of behaviour. First, we evaluated three weighted descriptors of network structure: nestedness, modularity, and specialization. Then, we calculated metrics of centrality and correlated them with plant traits. We recorded 271 visits by 22 bird species of eight families. The network is modular and specialized, showing that subgroups of *H. succosa* trees with different trait combinations attract different subsets of bird, in a way that specialist trees are not connected to a subset of the bird species that visit generalist trees. We also found that centrality metrics reached higher scores in plants with lower height, larger fruits, and intermediate sucrose content. Fruit handling was the predominant foraging behaviour in the multilayer network and represented 90 percent of the interactions. Downscaling a plant-frugivore network to its individual trees showed that the structure of the system is influenced by interindividual variations in the tree population, in which individuals with the best combination of traits occupied central positions in the network.

Forbidden fruits? Benefits and costs of seed dispersal by bats in agroforestry landscapes of India's Western Ghats

Kadambari Deshpande Abi T. Vanak, Mahesh Sankaran, M. Soubadra Devy & Jagdish Krishnaswamy

Assessments of ecosystem services underpinned by biodiversity are complicated due to simultaneous benefits and costs from biodiversity to people, and cultural perceptions. Old-world fruit-bats are important seed dispersers of many forest trees, but are also regarded as 'pests' of commercial fruits, and are increasingly being identified as disease reservoirs. In tropical agroforestry systems, where bat-human interactions are common, simultaneous benefits, costs, and risks from fruit-bats can generate trade-offs between "ecosystem services" and "disservices". People's values about bat-mediated ecological processes (e.g. seed dispersal) can vary in different socio-ecological contexts, and influence prospects for bat conservation. In this regard, we investigated how seed dispersal benefits and costs from fruit-bats varied

across cashew plantations in India's Western Ghats. We conducted 165 detailed interviews with plantation owners/workers across 5 states (Maharashtra-Goa-Karnataka-Kerala-Tamil Nadu) to record perceived benefits and costs from bats, field measurements of seed aggregation/dispersal by bats feeding on cashew-apples in plantations (N = 10), and assessed potential bat-human contact pathways that could predispose viral transmission risk. Contributions of bats to cashew "rain" and aggregation under feeding trees/night roosts were thrice higher (50%-60% of cashew-nut production per season) than nuts dropped without bat involvement, in sites with patchy distribution of plantations. Plantation workers identified bat-dropped nuts as "collection-ready", as bats only fed on ripe cashew-apples. Workers attributed nut-aggregation by bats to be beneficial for reducing human labour in nut collection. But plantation managers perceived 10%-15% losses from bats dispersing nuts outside plantations. Across sites, we estimated net positive benefits to plantation farmers from seed-aggregation by bats. We also identified bat-human contact pathways related to plantation activities, which could influence viral disease risks to people in the future. Improving awareness, safe fruit/seed handling, bat monitoring, and adaptive management practices could maximize socio-ecological benefits and reduce the risks from bat seed dispersal in tropical agroforestry landscapes of the Anthropocene.

The role of urban avian frugivores in dispersal of horticultural introductions *Purabi Deshpande*

Urban environments are hotspots for introductions of non-native species, particularly plants, from where they can then spread into the surrounding natural environment. The phenologies of native animals and plants are in flux due to climate change, potentially altering the interactions taking place over fruit dispersal. Therefore, changing distributions of birds in urban environments, in particular, could play a crucial role in driving the spread of plants into the wilderness. Using 32 years of data from monitoring of overwintering birds in Finland, we explored whether birds move between forest, rural and urban habitats. Additionally, we conducted line-transect surveys in Helsinki, during the autumn migration season to track the fruiting phenology of native and non-native plants and fruit removal rates by avian frugivores. We find that overwintering birds move between urban, rural, and forest habitats in response to changes in snow cover, with more birds moving to rural habitats when the snow depth is low and urban habitats when it is high. Additionally, when birds were divided into feeding guilds, while snow cover did not have any impact on the different feeding guilds in urban habitats, rural habitats retained higher numbers of tree or bush feeding birds compared to ground feeding birds. In Helsinki, we found that more than 50% of the samples of fruiting plants were not native to Europe. Urban birds consumed fruits from both native and non-native plant species. These results highlight that the dispersal potential of non-native plants in urban environments is increased by birds moving between urban and rural areas. As birds do not show a preference for native species, the repeated introduction of non-native species in urban areas could lead to potentially detrimental biological invasion by non-native species. These results also highlight which plants should be planted in cities to harbour avian biodiversity while protecting natural environments.

S Downsizing of animal communities trigger stronger functional than structural losses in seed-dispersal networks

Isabel Donoso, Marjorie C. Sorensen, Pedro G. Blendinger, W. Daniel Kissling, Eike Lena Neuschulz, Thomas Mueller & Matthias Schleuning

Downsizing of animal communities due to defaunation is prevalent in many ecosystems. Yet, we know little about the consequences of downsizing for ecosystem functions such as seed dispersal. Here, we use eight empirical seed-dispersal networks sampled across the Andes and simulate how downsizing of avian frugivores impacts the structural stability and ecosystem function of these networks. We use a trait-based modelling framework to quantify the consequences of downsizing—relative to random extinctions—for both secondary plant extinctions (as a measure of structural stability) and long-distance seed dispersal (as a measure of ecosystem function). We found that downsizing led to stronger functional than structural losses. For instance, 10% size-structured loss of bird species resulted on average in 35% decline of long-distance seed dispersal, but only in few secondary plant extinctions. Our simulations reveal that structural changes in ecological networks are insufficient to represent the consequences of animal extinction and downsizing for ecosystem functioning.

S Role of native avian frugivores in germination facilitation and potential dispersal of invasive American bramble in South Africa

Colleen T. Downs, K.L. Molefe, M.J. Tedder, V. Thabethe & I. Rushworth

Frugivorous birds are important in the dispersal of many fleshy-fruited plant species, including invasive plants. Consequently, we investigated three native frugivorous avian species' role in potential dispersal and germination success of the invasive American bramble (*Rubus cuneifolius*) in South Africa, particularly in terms of the amount of fruit ingested, transit time, and their effects on seed germination. Three common species of frugivorous bird species were predicted to positively affect the spread of invasive *R. cuneifolius*. The bird species (Speckled Mousebird *Colius striatus*, Red-winged Starling *Onychognathus morio*, and Common Bulbul *Pycnonotus barbatus*) were fed *R. cuneifolius* fruit in captivity and amounts ingested were determined together with transit times. Seeds that were excreted and/or regurgitated by the three bird species, manually extracted seeds, and control whole fruit were then planted and their germination assessed daily. Although the three bird species varied in the amount of fruit consumed (~ 10-30 g), there was no significant difference in the amount of *R. cuneifolius* fruit eaten per gram body mass among the species. Bird-ingested seeds emerged a mean 21-23 days after planting, while the seeds from the whole fruit took longer to emerge (mean 28 days). Germination of seeds ingested by the respective bird species was significantly higher (~ 60-75%) than seeds manually removed from fruits (~ 52%) or seeds in whole fruits (~ 7%). This suggests that removal of pulp and seed coat abrasion by the birds increased germination success. All the three species had seed transit times greater than 20 min., demonstrating their potential to disperse seeds a distance away from the parent plant. The results showed that the three bird species increased the germination success and suggests they are potentially important dispersers of the invasive *R. cuneifolius*.

S Trait matching in Neotropical palm-frugivore interactions

Caroline M. Dracxler & W. Daniel Kissling

Fruit size is one of the main factors constraining plant-frugivore interactions since it limits the size range of animals that can consume the fruits and disperse its seeds. As a consequence, size-selective defaunation has potential to affect seed dispersal interactions as well as selective pressures on fruit traits. Here, we test to what extent interactions between Neotropical palms (Arecaceae) and different taxonomic groups of frugivores are shaped by fruit size, and how extinctions might influence this relationship. We used a comprehensive database on pairwise palm-frugivore interactions, derived a meta-network, and compiled trait data of both palms (fruit length and fruit width) and frugivores (body mass as a proxy for gape width). We tested for trait (i.e. size) matching between frugivores and the palm species they feed upon, using a network approach. We found high modularity, with modules containing palm species that are mainly consumed by particular frugivore taxonomic groups. However, a size-matching relationship rarely emerged, possibly because large mammals (i.e. megafauna) are mostly extinct, and because relatively small animals act as the most important consumers of Neotropical megafaunal palm fruits. We conclude that considering megafauna is essential to fully understand trait matching and the future of palm-frugivore interactions in the Neotropics.

O Effects of forest fragmentation on avian frugivore community assemblages in Indian Ocean Coastal Belt Forest, KwaZulu-Natal Province, South Africa

David A. Ehlers Smith, Yvette C. Ehlers Smith & Colleen T. Downs

Ecosystem functioning is dependent upon the ability of species to disperse through and persist in fragmented habitats within anthropogenic land-use matrices. Seed dispersal may be threatened by changes in frugivore assemblages as fragmentation gradients become more severe. To test this, we conducted 260 fixed-radius avian frugivore point-count surveys across 123 distinct habitat patches of the Indian Ocean Coastal Belt Forest, KwaZulu-Natal, South Africa, during both the non-breeding and breeding seasons. We conducted surveys of tree species richness and habitat structure at each survey location and assessed landscape-scale fragmentation metrics of each habitat patch. We calculated alpha (α) and beta (β —overall, nestedness, turnover) avian frugivore and tree species richness and functional trait diversity (functional richness, evenness, dispersion). Habitat structural complexity had a positive effect on functional α -evenness and functional α -dispersion of avian frugivores and tree species α -richness, but not on frugivore α -species or functional α -richness. Increasing forest-patch size had a positive effect, and increasing patch isolation had a negative effect, on avian frugivore species α -richness and functional α -richness, and tree species α -richness and functional α -richness, but no effect on other measures of avian frugivore functional α -diversity. Overall tree species β -diversity change was driven by increasing forest-patch size and isolation distance. Increasing forest patch size drove tree species nestedness but isolation had no effect. Increasing forest-patch size drove tree species turnover negatively, while increasing isolation distance had the opposite effect on tree species turnover. Overall avian frugivore β -diversity change was not driven by forest-patch size nor isolation distance, and the isolation effect had no influence on avian frugivore species nestedness nor turnover. Increasing patch size drove frugivore species nestedness positively and frugivore species turnover negatively. Observed changes in avian frugivore and tree assemblages implied that anthropogenic forest fragmentation was eroding seed-dispersal networks, with negative implications for forest persistence and regeneration.

Trees alone don't make a forest: assessing factors influencing forest regeneration within a fragmented habitat mosaic.

Yvette C. Ehlers Smith, David A. Ehlers Smith & Coleen T. Downs

South African forests have a history of utilization, ranging from clear-felling to subsistence harvesting of products. Forests have been allowed to regenerate in some areas in the absence of fire regimes. Here, we assessed the factors allowing for the persistence and regeneration of forests within a fragmented forest mosaic, mediated by avian frugivores. We conducted fixed-radius point-count surveys during the breeding season across 117 individual forest patches within the Indian Ocean Coastal Belt of KwaZulu-Natal, South Africa. We quantified the foliage profile and collated a tree species list at each survey point. Landscape-scale factors and patch characteristics were extracted from Geographical Information System (GIS) data layers. We calculated avian frugivore and tree species richness and avian frugivore functional trait diversity (FD; functional richness, evenness, dispersion) for each habitat patch. Using fourth corner analysis in the 'mvabund' package in R, we assessed tree species presence/absence as a function of patch characteristics (including frugivore FD), tree species traits, and their interaction. Our results showed that regenerating forest patches were dominated by pioneer tree species, tree species that were dispersed by animals, and those that exuded gum or sap. Fruit size did not have an impact on these interactions. These patches were influenced positively by frugivore functional evenness, which suggested that niche space was sufficiently used by avian frugivores, thus implying ecosystem reliability and productivity. High avian relative abundance appeared to be an important factor for driving forest regeneration, as functional evenness is abundance weighted. Therefore, we recommend measuring avian abundance and functional diversity, in addition to species richness, when assessing the roles of avian frugivores in forest ecosystem dynamics.

Seed dispersal by animal frugivores and range expansion in plants: a multilayer network approach.

Jorge Isla Escudero, Miguel Jácome Flores, Daniel Pareja Bonilla & Pedro Jordano Barbudo

An important consequence of modern global change is that many species world-wide are expanding their distribution ranges in response to changes in land-management and conservation policies. Along with abiotic conditions, biotic interactions represent a key factor in plant species evolution, population maintenance and movement opportunities. Studying biotic interactions of different nature can be compelling due to their variability, context-dependency, and variable ecological effects. Therefore, the simultaneous study of different interaction types remains poorly explored. Our work aims to unravel how the main different interaction types throughout the seed dispersal-early regeneration transitions are structured from an individual plant standpoint along a habitat expansion scenario. We use novel techniques such as the analysis of multilayer networks, exploring at the individual tree level how the mutualistic (seed dispersers) and antagonistic (pulp consumers, seed predators, herbivores) animal partners overlay their interactions and generate variable outcomes of seed dispersal success. One of the main theoretical challenges that we face, consists in the construction of the inter-layer links among interaction layers. These inter-layer links will be based on the fitness consequences of each interaction type. In the Doñana's Biological Reserve (Spain) we use as a biological model the Phoenician Juniper (*Juniperus phoenicea*). This gymnosperm has berry-like arceuthides that are dispersed by medium- to large-sized vertebrates including migratory thrush species and mammals such as badgers or foxes. We study three plant populations with variable degrees of stand maturity, focusing on 35 individual trees per population for which we monitor all interacting partners and biological traits. Individual plant traits and stand maturity reshape the interaction assemblages for individual trees, promoting highly variable regeneration scenarios. Our results illustrate how we can identify key species and interactions for plants movement and range expansion, a crucial goal in the current biodiversity crisis.

S Intertwined effects of defaunation, increased tree mortality, and density compensation on seed dispersal across a heterogeneous landscape

Jose M. Fedriani, David Ayllón, Thorsten Wiegand & Volker Grimm

Defaunation and increased tree mortality are major global change components occurring in many human-altered ecosystems. Whether these two stressors interact, leading to non-additive effects on ecosystem functioning, remains largely unknown. We combined long-term field data with individual-based modeling to investigate the intertwined effects of seed disperser loss, increased tree mortality, and density compensation on seed dispersal kernels in a heterogeneous landscape. Our simulation experiments showed that both stressors markedly limit not only the quantity of seed dispersal but also its quality since the impact on seed arrival strongly varied among habitat types strikingly differing in suitability for tree establishment. Density compensation generally had a marked positive effect on seed arrival which, however, was largely limited under increased tree mortality. Finally, defaunation and increased tree mortality did not act in an additive fashion, which highlights the need to account for the joint operation of multiple stressors to predict impacts on ecosystem functioning.

P Induced Seed Dispersal by frugivorous vertebrates at a restored forest in southeastern Brazil

Brazil José Otavio Venancio Ferreira, Wesley Rodrigues Silva & Jasmim Oliveira.

The restoration needs of degraded ecosystems are pressing. To enhance the restoration process, we have developed a technique called Induced-Seed-Dispersal (ISD) that aims to ease seed dispersal limitation at restored sites by flora enrichment. This enrichment is done through the offer of seed species that are rare or absent in the habitat, inside banana pulp, to frugivorous vertebrates at artificial feeders. We assessed the effectiveness of ISD in introducing a plant species into the area of interest and its effect on the dispersal of other endozochorous seed species. This study took place in a restored field at Campinas-SP, Brazil, between August 2017 and July 2018. We introduced *Cecropia hololeuca* at this site by providing, weekly, four bananas with 1500 *C. hololeuca* seeds at an artificial feeder. We recorded animal feeding events at the feeder with a camera trap. We assessed the abundance of offered seeds in the seed rain and their dispersal distances using seed traps around the feeder. We verified both seed germinability and gut passage effects by in vitro germination experiments. Furthermore, we determined the abundance and richness of other zoochorous seeds in the seed rain around the feeder for comparison with the data of a control area, where ISD was not applied. Offered bananas and *C. hololeuca* seeds were greedily consumed by frugivores, the main ones being marmosets (*Callithrix penicillata*) and opossums (*Didelphis aurita*). Despite the low seed recapture, viable *C. hololeuca* seeds were recaptured in the seed rain even at the most distant seed traps (60 m). Marmosets had a positive gut passage effect on the germination rate of *C. hololeuca*. We did not observe an effect of the weekly fruit offer on the abundance or richness of other zoochorous seeds. We conclude that the application of this technique has great potential for enriching the flora of recovering fields.

S Roads disrupt seed dispersal in animal-mediated plants in tropical forests

Pierre-Michel Forget, Aurélie Albert, Olivier Boissier, Opale Coutant, Axelle Bouiges, Caroline Dracxler, Marion Ducrettet, François Feer & Irène Mendoza

Ecological interactions are being affected at unprecedented rates by human activities. Yet, the continuity of ecological functions such as seed dispersal is crucial for forest regeneration. We assess the level of seed removal and frugivore activity at four animal-dispersed tree species in order to evaluate the health status

of the nearby mature forest of a recently-open road in Guyane. We counted fallen fruit, fruit valves, and seeds in single 1 m² quadrats under focal fruiting tree species scattered in forest corridors and further away along the 50-km road ($N \geq 30$ trees per genus). We calculated the proportion of fruits opened and consumed, and the proportion of seeds removed by animals (between 2009–2019). In addition to the direct visual sightings during sampling, we used automatic remote cameras to identify both ground- and canopy-dwelling wildlife during fruiting periods in the forest nearby the road (2013–2019). Our results showed that the proportion of fruits opened and consumed, and the level of seeds removed in the forest within the vicinity ($< 1\text{--}2$ km) of the road is ca. 30–50% lower than previous observations carried out at a remote control forest (Natural Reserve of Nouragues). Our indices also confirm that large birds and both small body-sized diurnal and nocturnal arboreal frugivores are the main consumers and seed dispersers remaining in the forest nearby the road. We also show that the primate-specialist tree species are more affected by road proximity than vertebrate-generalist tree species thanks to some compensatory effects by lesser frugivores when larger primates are barely present. Therefore, despite efforts to preserve forest continuity (vegetation bridges over the asphalted road), increased hunting pressures in forests nearby the road remains the main driver of defaunation, which has affected ecological processes such as seed dispersal less than a decade after the road was opened to traffic.

P Introduced species in plant-frugivore networks: assessing impacts on network biogeography and predicting interactions under climate change

Evan Fricke & Jens-Christian Svenning

Introduced plants and frugivores have integrated into local plant-frugivore networks. How has this influenced biogeographic patterns among plant-frugivore networks? What lessons can we learn from introduced species' roles when projecting novel dispersal interactions under global change? We will report the use of a newly assembled database of local plant-frugivore networks to answer these questions. We assembled network data from the literature as well as plant and animal trait data from publicly available global databases. We analyzed biogeographic patterns in the global meta-network (considering all interactions observed at any study location) before and after removing interactions involving species in their introduced range. Using phylogenetic imputation of missing traits and machine learning methods, we developed models to predict dispersal interactions. We found that species introductions reduce the natural biogeographic pattern of the global meta-network. Plant-frugivore interactions involving introduced species are increasingly prevalent over time (a 7-fold increase over the last 75 years) and are more common in anthropogenically impacted environments (on average 8 times more common in the most versus least human-impacted study sites). Our models achieve roughly 85% accuracy to predict interactions using observed interactions with introduced species as a proxy for novel interactions, in other words by training machine learning models using only native-native interactions and then predicting what interactions occur given the observed species composition of invaded networks. This work shows that introduced species are eroding natural biogeographic patterns across plant-frugivore networks. This accelerating trend is likely to influence which plants and animals are winners and losers in future ecosystems, and our predictive models show that we have reasonable ability to predict which species will maintain dispersal function in future environments. Although improved data on species traits and abundance will strengthen our predictive capacity, this work shows promise for global-scale syntheses of mutualistic network data for understanding mutualism macroecology and forecasting global change responses of plants and frugivores.

S Palm tree-bird interaction network: do bird species and their roles change with Atlantic Forest types in southeast Brazil?

Pâmela Friedemann, Marina Corrêa Côrtes & Paulo Roberto Guimarães Junior

Intraspecific phenotypic variation and habitat structure may influence the interactions between partner species, compelling individuals to consume resources differently, and implying different disperser coteries. We aim to characterize the network between avian frugivores and the ecologically important palm *Euterpe edulis*. Fruit-eating events were observed in 102 palm individuals in three Atlantic Forest types in southeast Brazil. To identify the bird species playing a central role in the network, we measured the proportion of individual palms visited (PIV) by each bird species and the mean shortest path (MSP) connecting a given species to all other species and individual palms in the entire network, and in the networks separated by forest type. Sixty-two palm individuals were visited by at least one bird and 12 bird species were recorded. For the entire network, *Turdus flavipes*, *T. albicollis* and *Procnias nudicollis* were the species with highest PIV and lowest MSP. In the premontane forest, *T. flavipes*, *T. albicollis* and *Selenidera maculirostris* had the highest PIV, and *T. flavipes*, *T. albicollis* and *P. nudicollis*, the lowest MSP. In the restinga, *T. albicollis* showed the highest PIV and lowest MSP, and in the lowland forest, *Ramphastos vitellinus* and *Pyroderus scutatus* were considered important species in the network. The relevance of thrushes (*Turdus* spp.) to network structure may be a consequence of their high abundance, potential preference for *E. edulis* fruits (*T. flavipes*), and the ability to forage in different habitats and vertical forest strata. Other important species are highly frugivorous and large-bodied, thus able to consume many seeds and ingest fruits regardless of size. These results indicate that species capable of inhabiting different habitats and that consistently visit fruiting trees tend to play a central role in networks. In the next step of our project, we will explore how individual characteristics of palms affects disperser composition.

O The role of the brown bear as a seed disperser: a review

Alberto García-Rodríguez, Jörg Albrecht, Sylwia Szczutkowska, Alfredo Valido, Nina Farwig & Nuria Selva

Frugivory and associated seed dispersal are important ecosystem functions that, in temperate regions, are carried out mainly by mammals and birds. Brown bears *Ursus arctos* are likely to have a particularly strong impact as they consume large amounts of fruits, especially during late summer and autumn, when seeds can be dispersed over long distances. We investigated the importance of brown bears as seed dispersers across their distribution area worldwide. We reviewed data from 96 publications about brown bear's diet (Europe = 25, Asia = 30 and North America = 41 studies) and extracted information about the importance of fruits consumed by the species (species eaten, frequency of occurrence, relative volume and relative energy content). Brown bears eat at least 205 fleshy-fruited plant species belonging to 24 families, with Rosaceae and Ericaceae comprising almost half of the total. Additionally, some of the families are relevant in one continent but they are completely absent in the others. European bear populations disperse the largest number of species and seem to be more fruit-dependent in terms of volume, while we did not find any difference in energy content derived from fleshy fruits among continents. Most of the families dispersed by bears are biome-specific. Brown bears inhabiting forested ecosystems disperse a higher number of fleshy-fruited plant species at southern latitudes (Mediterranean and mixed forests), but the largest contribution in terms of both volume and energy occurs at northern latitudes (boreal forests). We also provide experimental evidence that brown bear ingestion do not usually damage the seeds and that, for most species, germination rates after bear ingestion increase when compared to both whole fruits and manually extracted seeds. We conclude that brown bears are legitimate seed dispersers but more research is needed about how the species influences plant population dynamics of particular species it disperses.

O Seed dispersers inflate kinship in a bout, but promote genetic admixture within the neighbourhood in the long-term

Pedro J. Garrote, Antonio R. Castilla & Jose M. Fedriani

Pioneer nurse species are key on the oldfields' recolonization. Specifically, they can play a critical role for the recovery of ecosystem functioning by promoting the assemblage of dispersers' communities and by facilitating the arrival of woody plant species. Here, we have focused on the role of frugivores influencing the genetic composition of the seed rain of *Chamaerops humilis*, a keystone species on the recolonization of Mediterranean oldfields. For two years, we conducted intensive fieldwork to examine the spatial distribution of the seed rain. Furthermore, we screened all the emerged seedlings ($N = 104$) and reproductive plants at 12 microsatellite markers. We analyzed the kinship between individuals and fine-scale spatial genetic structure using the software Spagedi 1.4. We found inflated kinship among seedlings within faeces. Specifically, seedlings were on average half-sibs (mean $F_{ij} = 0.12 \pm 0.02$) and 8.3-fold greater than for adults. At a population level, we found 84% of non-related seedlings while 10.5% and 5.5% were half- and full-sibs. Within latrines, we detected on average 78.9% of non-related, 7.6% of half-sibs, and 13.5% of full-sibs while for isolated faeces the percentages were 39.9%, 22.2%, and 37.9% respectively. Our results revealed inflated kinship between seedlings coming from a single dispersal event, but decreased kinship between seedlings at greater spatial scales (latrines, population). Our results suggest the existence of temporal changes in the preference of dispersers for fruiting plants. In a single bout, dispersers defecate mostly seeds with inflated kinship suggesting that they preferentially concentrate consumption in a single plant. However, as the fructification season progresses, the dispersers consume fruits of different plants and add their seeds in the latrines enhancing the levels of genetic admixture. We provide evidence of the relevance of dispersers on the recolonization of Mediterranean oldfields by mixing the genotypes of a keystone species across time and space.

S Non-native mammals as seed dispersers or seed predators in a novel ecosystem

Ann Marie Gawel & Haldre Rogers

Non-native species have caused ecological harm in many ecosystems, but they can also play beneficial roles when native species are missing. We tested the roles of two non-native mammals in the forests of the island of Guam, which, due to invasive brown tree snakes (*Boiga irregularis*), are devoid of native birds, the island's main seed dispersers. Feral pigs (*Sus scrofa*) are abundant in Guam's forests, but rats (*Rattus* spp.) are uncommon in forests due to predation by snakes. We conducted feeding trials with captive rats and pigs in Guam to determine their roles in either seed dispersal or seed predation. We fed over 20 species of fruits to rats and pigs, and tested germination of gut-passed and handled seeds. Rats destroyed most of the seeds that they were fed. Pigs swallowed many seeds whole and passed them intact, but this was highly correlated to the number of seeds per fruit and the size of the seeds. Both rats and pigs consistently cleaned the flesh off of larger-seeded fruit species, resulting in improved germination for these seeds. While pigs did successfully pass more seeds than rats, this was species- and size-dependent, and pigs still destroyed or ignored some seeds. These species-specific effects of non-native species need to be considered as plans develop to control invasive snakes and ungulates in order to restore Guam's forests. Further, as novel ecosystems become the norm globally, we are pressed to better understand the mixed roles of native and non-native species in these altered systems.

S Seeds and the city: The interdependence of zoochory and urban ecosystem dynamics, and its implications.

Tiziana A. Gelmi Candusso & Anni Hämäläinen

Animal-mediated dispersal may be disproportionately affected by urbanization, as many animals avoid urban areas or restrict their movements within urban habitats. This could alter the efficiency of animal dispersal vectors and modify seed movements across urban habitats. While recent studies suggest that seed dispersal networks can be complex and dynamic even in highly managed green areas with relatively low biodiversity, zoochory in urban environments remains understudied. During this talk we will assess the ecological and evolutionary consequences for seed dispersal following urbanization by considering specific features of urban environments. These include the complexity of habitats with varying continuity, high disturbance and intense management, a high proportion of alien species combined with low natural biodiversity, animal behavioral adjustments in different urban settings, and rapid evolutionary change due to urbanization. We will understand how urbanization disrupts and alters zoochory processes, and how successful zoochory can, in turn, alleviate or worsen the challenges to ecosystem dynamics originating from increased urbanization. We will also discuss further uses of studying urban seed dispersal, such as the use of dynamic urban seed dispersal networks as models for the adaptability of seed dispersal communities and conservation measures that can be derived from the study of seed dispersal in urban environments.

S Effects of howler monkey reintroduction on ecological interactions and processes

Luisa Genes, Fernando A.S. Fernandez, Fernando Z. Vaz-de-Mello, Patricia da Rosa, Eduardo Fernandez & Alexandra S. Pires

Rewilding has been an increasingly popular tool to restore plant-animal interactions and ecological processes impaired by defaunation. However, the reestablishment of such processes has seldom been assessed. We investigated the restoration of ecological interactions following the reintroduction of the brown howler monkeys (*Alouatta guariba*) to a defaunated Atlantic forest site. We expected the reintroduction to restore plant-animal interactions and interactions between howlers and dung beetles, which promote secondary seed dispersal. We estimated the number of interactions expected to be restored by the reintroduction to provide the baseline interaction richness that could be restored. We followed the reintroduced howler monkeys twice a week for 24 months (337 hours total) to assess their diet. We used howler monkey dung in secondary seed dispersal experiments with 2484 seed mimics to estimate the removal rates by dung beetles and collected the beetles to assess community attributes. We compared the potential future contribution of howler monkeys and other frugivores to seed dispersal based on the seed sizes they disperse in other areas where they occur. In 2 years, howler monkeys consumed 60 animal-dispersed plant species out of the 330 estimated. Twenty-one dung beetle species were attracted to experimentally provided dung; most of them were tunnelers, nocturnal, and large-sized (> 10 mm). On average 30% (range 0-100%) of the large seed mimics (14 mm) were moved by dung beetles. About 91% of the species consumed by howlers (size range 0.3-34.3 mm) overlapped in seed size with those removed by dung beetles. In our study area, howler monkeys may consume more large-seeded fruit species than most other frugivores, highlighting their potential to affect forest regeneration. Our results show reintroductions may effectively restore ecological links and enhance ecological processes.

S Predicting the effects of climate change on fruiting phenology *Liba Pejchar Goldstein, Manette Sandor, Clare Aslan & Judie Bronstein*

Phenological shifts are a widely studied consequence of climate change. However, the effect of such shifts in a particular life history stage on subsequent stages has not been well examined. Although flowering times are often observed to be advancing with climate change, whether fruiting phenology is shifting in tandem is poorly understood. Seed dispersal, which concerns the fruiting life stage, is essential for plant populations. With climate change, phenological mismatch between plants and their animal dispersers could occur, leading to reduced seed dispersal and plant recruitment. In the absence of widespread, long-term fruiting phenology data, predicting whether and to what extent mismatch will occur depends on understanding if flowering and fruiting are tightly linked or if these processes respond differently to environmental change. We propose a suite of testable hypotheses about these life stages and, through a case study, present evidence of shifts in fruiting and changes to the length of time between flowering and fruiting. These findings add to the small body of evidence that fruiting phenology is shifting, and enable us to begin to explore the mechanisms through which these shifts are occurring. We suggest that our suite of hypotheses provides a pathway for advancing the ecology of seed dispersal dynamics in a changing world.

O Frugivorous birds operating as 'mobile links' in anthropogenic landscapes *Juan P. González-Varo*

Animals that actively move in fragmented landscapes and connect habitats through ecological processes are termed 'mobile links'. Frugivores play a major role as mobile links in the increasingly fragmented landscapes of the planet, fostering regeneration of disturbed habitats and functional connectivity among fragments. Despite the relevance of these functions, we know little about how different frugivores disperse seeds in anthropogenic landscapes. I will summarise recent studies aimed at unravelling mobile-link functions by frugivorous birds. We combined field sampling of bird-dispersed seeds in the forest and matrix of fragmented landscapes and the use of DNA markers for subsequent identification of disperser species and source plants. We found a huge functional complementarity among frugivore species in terms of landscape-scale seed deposition, which resulted in gradual turnovers in seed-rain contributions from the forest to matrix areas far from the forest edge, where open-habitat frugivores replaced forest-dependent frugivores. Such complementarity was also remarkable in terms of seed deposition at natural or anthropogenic perches in the matrix, and canopy-cover dependence. We also found that the seed rain mediated by a woodland-dependent bird was confined to the forest most of the year, but this bird contributed a peak of seed-dispersal events in the matrix during a short period, attributable to dispersing juveniles that left the forest after emancipation. Hence, juveniles of habitat-specialist frugivores can contribute to functional connectivity transiently, but in a seasonally predictable way. Our results provide a comprehensive view of the way in which frugivores disseminate seeds through real-world landscapes, and uncover key mechanisms behind the relationship between frugivore diversity and landscape-scale seed dispersal. They also evidence the importance of intraspecific variability for the 'mobile-link' concept, broadening its application at within-species levels. On the applied side, these findings can help us to understand and forecast passive restoration and plant invasions at degraded habitats.

P Differential impacts of forest cover loss on frugivory and seed predation of four rainforest tree species in the southern Western Ghats, India

Abhishek Gopal, Rohit Naniwadekar & Divya Mudappa

The seed dispersal cycle is a crucial ecosystem process aiding in the persistence and colonization of trees. Forest fragmentation has been shown to disrupt seed dispersal and seed predation, which are the two crucial stages in the cycle. However, the consequences of this are poorly understood in fragmented forests of South Asia. In a heterogeneous production landscape in southern Western Ghats comprising primarily of tea and coffee plantations with pockets of forest fragments, we examined the effects of forest cover loss (proportion of forest cover in a 500 m radius around the focal tree) on frugivory and seed predation of four rainforest tree species, *Persea macrantha*, *Heynea trijuga*, *Myristica dactyloides*, and *Canarium strictum*, with varying seed sizes. For frugivory, 131 individual trees (≥ 30 per species) were observed for 623 hours. For seed predation, seed fate of ≥ 440 seeds per species was tracked using seed plots placed under at least 11 individual trees per species. Effective frugivores were identified using the seed dispersal effectiveness framework and their response to the predictors was examined. The frugivore assemblage varied across the four tree species and frugivores varied in their response to forest cover and fruit crop size. Loss in forest cover negatively affected the visitation of the medium-seeded *P. macrantha* but positively affected the large-seeded *M. dactyloides*, whereas, *H. trijuga* and *C. strictum* had very few visitations. Seed predation by vertebrates was not influenced by forest cover but by seed traits. Medium-seeded tree species and tree species with softer seed coats were more likely to be predated as compared to large-seeded tree species and tree species with harder seed coats. This study highlights the variation in frugivory and seed predation to forest loss and points towards the differential role of factors like forest cover, plant and frugivore traits, and the matrix in influencing frugivory and seed predation.

S Internal and external dispersal of plants by waterbirds

Andy J. Green & Adam Lovas-Kiss

We review several recent studies that assess the relative importance of epizoochory and endozoochory by migratory waterbirds. These indicate that endozoochory is generally a much more frequent process than epizoochory, both for short and long-distance dispersal. The importance of epizoochory has long been exaggerated in the literature, largely due to the mistaken belief expressed by Darwin that waterbirds destroy all ingested seeds during gut passage. This erroneous viewpoint remains influential. Epizoochory is more important for mammals than for birds. Waterbirds spend an important fraction of their day preening, and seeds stick in fur more easily than feathers. Other recent studies have advanced our understanding of what plants are dispersed by waterbirds through endozoochory, but the amount of research conducted since Proctor (1969) is still surprisingly small. We are finding a considerable degree of overlap between the plants dispersed by waterbirds and those dispersed by mammals (especially ungulates), as may be predicted from Janzen's (1984) foliage is the fruit paper. There is also overlap with plants dispersed by terrestrial birds such as corvids. Which plants are "super-dispersers" through both mammals and birds requires focused investigation at the landscape scale, e.g. in seasonally flooded grasslands. Another important finding shared with ungulates is that morphological dispersal syndromes (functional traits) are hopeless at predicting endozoochory by waterbirds, something we will illustrate in detail. This brings into question the validity of recent studies predicting historical, current, and future dispersal patterns based on dispersal syndromes of entire floras, which assume that endozoochory only occurs for plants with an "endozoochory syndrome". We present preliminary research that illustrates how alternative seed traits may be better predictors of endozoochory potential.

S The disruption of São Tomé seed-dispersal networks by alien vertebrates

Ruben Heleno, Ana Coelho, Filipa Mendes, Jorge Palmeirim, Jaime Ramos, Ana Rainho & Ricardo de Lima

Biological invasions are a major threat to global biodiversity, and their disruptive potential is particularly relevant on the native communities of oceanic islands. We evaluated the potential effect of introduced vertebrates on the seed dispersal network of São Tomé, a volcanic island in the Gulf of Guinea. Our goals are: 1) characterize the São Tomé seed dispersal network; 2) evaluate the consequences of combining several sampling methods; and 3) assess the functional role of introduced dispersers and their potential to disrupt native seed dispersal networks. We compiled interactions between plants and their vertebrate seed dispersers through five complementary sampling methods, across one year: direct observations, literature review, questionnaires, faecal samples, and stomach content analysis. The São Tomé network revealed 419 interactions between 22 disperser species (12 birds, 2 bats, 1 snake, and 7 non-flying mammals) and 150 plant species. The questionnaires proved to be the sampling method that contributed most interactions, followed by faecal and stomach content analyses. Each sampling method proved to be particularly informative for a small group of dispersers, and therefore their results are largely complementary. Two of the most frequently dispersed plants, *Cecropia peltata* and *Rubus rosifolius* are highly invasive. Native and introduced dispersers did not differ significantly in the number of dispersed species, their specialization or their strength, however introduced dispersers tended to have broader gape widths and to disperse larger seeds. Our results point to an important disruptive potential of introduced dispersers, by altering the selective pressure in favour of species with larger seeds. However, these differences were not reflected by common topological metrics of species interaction patterns, highlighting the need to consider biological traits while interpreting interaction networks.

P The role of parrots as seed dispersers in the scenario of biological invasions

Dailos Hernández-Brito, Guillermo Blanco, Martina Carrete & José L. Tella

Biological invasions cause perturbations in different ecosystem functions, in which novel interactions may emerge between invasive species and recipient communities, including plant-animal relationships such as seed dispersal. Parrots are one of the most traded bird groups worldwide, hence 16% of their species present populations out of their native ranges. For a long time, parrots have been widely considered as seed predators, this overlooking their role as seed dispersers. However, recent studies have questioned this antagonist vision and increased our knowledge of the role of parrots as seed dispersers at different mutualistic levels. Here, we recorded observations of 19 invasive parrot species established in five locations from three different continents, to identify those feeding behaviours that could cause seed dispersal. Recorded invasive parrots developed plant-animal relationships with 150 different plant species and our results show that (1) all recorded parrot species dispersed fruit and seeds by stomatochory over a wide range of distances ($SD = 45$ meters); (2) 80% of recorded feeding events derived in food wasting that may assist secondary seed dispersal; (3) consequently we observe different food facilitations that involve 41 species of invertebrates and vertebrates; (4) presence of endozoochory after the analysis of parrot faecal samples that contain viable seeds from 15 different plant species. Our study provides growing support for the hypothesis that parrots also have a role as seed dispersers in invaded environments. The mere emergence of novel plant-animal relationships may trigger negative cascading effects on recipient plant communities (i.e. assisting invasion success of invasive plants and invasional meltdown processes), thus increasing the magnitude of impacts caused by invasive parrot species.

Bird functional traits as drivers of interlinked pollination and seed dispersal networks

Sandra Hervías-Parejo, Cristina Tur, Ruben Heleno, Manuel Nogales, Jens M. Olesen & Anna Traveset

Pollination and seed-dispersal networks might be coupled as they are the two key reproductive mutualisms in plants, and also because pollination is a pre-requisite for the formation of fruits and seeds. Nevertheless, the intricacies of these two mutualisms combined are rarely addressed. Here we analyze the interconnectivity patterns and structural properties of pollination and seed-dispersal networks and assess how their structure is related to bird traits (i.e. size and body condition) and abundance. Bird-plant interaction data were sampled on two Galápagos islands by collecting pollen and faecal samples from individual birds captured with mist-nets across an entire year. Both networks were highly interconnected by many bird species (80%) acting both as pollinators and seed dispersers of different plant species. Double mutualists (i.e. the same bird species pollinate and disperse the same plant species) acted as hubs in each of the networks, but their occurrence was less than 4% of all links. This small overlap of interactions between the two networks was only partially explained (42%) by differences in plant species composition while the remaining was attributed to the turnover of links among shared plant species. Both networks were nested (i.e. interactions of the specialized species were subsets of those of the generalized species). However, the seed-dispersal network was more specialized and modular than the pollination network, indicating that pollen/nectar consumption by birds is a more opportunistic behaviour than fruit consumption. Species traits and abundance determined patterns of generalization (i.e. number of partners) across both ecological functions. Bird abundance was positively related to bird linkage level in both networks. Furthermore, larger birds dispersed the seeds of more plant species while healthier birds visited a greater number of flowering species. Bird species that were generalized in the pollination networks were also the most generalized in the seed-dispersal networks, showing the importance of generalist abundant species as couplers of multiple interaction networks, and thus for the total network stability.

P Plant-seed disperser interactions in fragmented lowland tropical forests of north-east India

Abir Jain, Rohit Naniwadekar, Navendu Page & G.S. Rawat

Globally, tropical forests face deleterious effects of forest fragmentation. Key ecosystem processes, like seed dispersal, that are known to be critical for the maintenance of tree diversity can be expected to be affected by fragmentation. There is a paucity of information on the impacts of fragmentation on plant-disperser communities from Asia. In this study, I compared plant-disperser communities between contiguous forests and fragments to determine organizational and compositional changes due to habitat fragmentation. I conducted the field study between January and April 2019 in lowland tropical evergreen rainforest fragments in Upper Assam, north-east India. I documented plant-frugivore interactions using a network of trails in two fragments (~ 25 km²) and compared them with a contiguous forest site (~ 100 km²). Trails were walked periodically across all sites (effort = 175 km in contiguous forests and 116 km in fragments). Spot censuses were carried out to record interactions on fruiting plants and used unweighted bipartite networks to compare network properties across fragmented and contiguous forests. I recorded a total of 556 interactions between 63 plant species and 44 avian frugivore species. Data analysis is under progress and preliminary results indicate that only 16% of the total interactions were shared between contiguous forests (unique = 131) and fragments (unique = 162). Climbers constituted an important plant group in network organization and small-bodied frugivores like bulbuls and barbets were the most connected seed dispersers (had more plant species partners). While *Ficus* spp. dominated in the absolute number of interactions, they had lower frugivore species partner than climbers. Relative proportions of interactions of small-seeded plants and open-forest birds were higher in fragments as compared to contiguous forests. Large-bodied frugivores like hornbills were observed even in 25 km² fragments. This study highlights that fragments can hold unique assemblages of plant-seed disperser interactions but may be compositionally different from the contiguous forests.

S SEADS, a simulation modeling framework to compare spatial patterns of seed deposition by sympatric animal dispersers

Landon R. Jones, Scott M. Duke-Sylvester, Paul L. Leberg & Derek M. Johnson

The spatial patterns of seed deposition by animal dispersers shape plant recruitment and demography in a changing world. However, complex interactions among the movements, physiologies, behaviors, and landscapes for animal dispersers can affect the quantity and quality of seed deposition for seed-dispersal effectiveness (SDE). To separate and quantify the relative contributions of these effects to spatial patterns of seed dispersal among sympatric dispersers, we created an individual-based modeling framework called SEADS (Spatially-Explicit Animal Dispersal of Seeds). For each disperser modeled, SEADS integrates their movements (direction, distance, frequency) and gut passage times of seeds with a spatially-explicit landscape. Additional input parameters and landscape changes can also be modeled in this framework. Simulation output includes measures of long-distance and contagious dispersal, which have important implications for seed survival and recruitment according to the Janzen-Connell hypothesis. We created several individual models from this flexible simulation framework to compare and explore the effects of disperser and landscape traits on spatial patterns of seed dispersal. In one example across a range of animal traits and habitat loss scenarios in a theoretical landscape, we found that habitat loss could lead to the trapping of dispersers in isolated fragments, resulting in low long-distance dispersal and high seed aggregation if disperser traits, particularly movement distance, did not permit them to escape (fragment entrapment). In another example, we compared two species of toucans in a fragmented agricultural landscape and found that keel-billed toucans (*Ramphastos sulfuratus*) were better dispersers of *Virola kochnyi* in forest, but collared araçaris (*Pteroglossus torquatus*) dispersed more seeds to potential restoration areas. Finally, we used SEADS to demonstrate that considering individual variation across dispersers compared to parameterizations using population means resulted in increased long-distance seed dispersal. Our flexible modeling framework could be broadly applied to compare the SDE of dispersers in a wide range of landscapes.

S Phenology and seed dispersal patterns in a tropical montane forest, Rwanda.

Beth Kaplin

Temporal and spatial patterns of fruiting phenology play a key role in animal movement patterns, foraging ecology, and seed dispersal, which in turn influence tree species distribution patterns. An especially interesting and not well understood aspect of this relationship is how shifts in availability of fruits and seed dispersers alters results of mutualistic seed dispersal interactions. We present an exploration of the implications of potential phenological uncoupling in tropical montane forest in Rwanda. We looked at this problem from several approaches. First, we explored how changes in phenological patterns along an elevation gradient interact with primate seed dispersal interactions. We focused on chimpanzees (*Pan troglodytes*), the largest bodied seed disperser present in montane tropical forests in Rwanda. Secondly, we analyzed patterns of seed handling and dispersal in chimpanzees across several forests in Rwanda with different elevations, sizes, and suites of fruit species to predict changes in mutualistic relationships with phenological shifts. Differences in temporal fruit phenology relative to elevation may influence chimpanzee patterns of seed dispersal in tropical montane forest in Nyungwe National Park, Rwanda and their role in seed dispersal of certain large-seeded late successional tree species. The abundance and distribution of *Ficus* species, an important fruit species in the chimpanzee diet, varied significantly across the elevation gradient and influences chimpanzee ranging. *Syzygium guineense* is highly consumed by chimpanzees when available and dispersed by chimpanzees through wadges, and showed variation in availability not only seasonally but by elevation. We compared chimpanzee fruit consumption and seed handling among three tropical montane forest sites of different sizes. Variations in abundance and availability of large-seeded species influenced seed handling and dispersal patterns. Comparisons of fruit availability with elevation and forest size indicate shifts in mutualist seed dispersal relationships, including changes in chimpanzee seed handling behaviors and variations in their interactions with plants.

S Understanding foraging behaviour of frugivores species at garbage dumps

Gitanjali Katlam & Soumya Prasad

The accumulation of plastic and other non-biodegradable substances discarded by human societies in natural ecosystems has been examined mainly in marine ecosystems. Trash is accumulating in terrestrial ecosystems as well, at an alarming rate. Trash attracts a host of wild and domesticated species to garbage dumps and poses a major threat to several endangered fauna. In the present study, we quantified the ecological impacts of garbage dumps located at forest edges on the behaviour of wild species. This study was conducted at Haridwar and Lansdowne forest divisions adjoining Rajaji National Park and Corbett Tiger Reserve. Garbage dumps of various sizes (< 100, 100-500 and > 500 m² area) situated near (< 100 m) and far (> 100 m) from forest edges, were sampled. We used scan/focal observation and passive-infrared camera trapping methods to document the visitation patterns of vertebrate species at these monitored sites. We also conducted opportunistic sampling of faecal samples to document plastic ingestion in the vertebrates. We conducted 200 hours of manual observations and 384 hours of camera trapping at garbage dumps. A total of 48 species were recorded out of which 16 species were facultative frugivores. These included mammals such as Rhesus macaque (*Macaca mulatta*), Terai Gray Langur (*Semnopithecus hector*), Golden Jackal (*Canis aureus*), Sambar Deer (*Rusa unicolor*), Indian Crested Porcupine (*Hystrix indica*) and birds such as Red-vented Bulbul (*Pycnonotus cafer*), Asian Pied Starling (*Gracupica contra*), Jungle Babbler (*Turdoides striata*). Additionally, analysis of elephant dung samples collected at or near garbage dumps revealed the presence of plastic and other non-

biodegradable material in over 35% samples indicating frequent elephant visits. This study is the first attempt to understand human-mediated resource use at garbage dumps by terrestrial species in India. The presence of frugivore species to garbage dumps is a significant indicator of a shift in their dietary spectrum to anthropogenic resources. These changes in diet might result in alteration in movement patterns, and subsequent changes in seed dispersal behaviour of these important species.

S Quantifying external seed dispersal by terrestrial mammals using camera trap data in a Japanese cedar plantation, central Japan

Shumpei Kitamura & Takuya Terashima

Numerous plants have seed-dispersal mechanisms that are associated with animals. Terrestrial mammals disperse more or less specialized seeds externally on their fur; yet, their effectiveness as seed dispersers is not systematically quantified at the community level. We investigated external seed dispersal by terrestrial mammals using camera trap data for seven years, in a Japanese cedar plantation, central Japan. Camera trapping of 3,480 trap days recorded 19,841 photos with 3,156 independent detections. Among the 16 mammal species photographed, seeds of epizoochorous plants were found in 8 mammal species: *Capricornis crispus* (267 photos with 942 seeds from 7 spp.), *Nyctereutes procyonoides* (25 photos with 2 seeds from 2 spp.), *Meles anakuma* (20 photos with 2 seeds from 1 sp.), *Sus scrofa* (44 photos with 115 seeds from 6 spp.), *Macaca fuscata* (37 photos with 33 seeds from 5 spp.), *Paguma larvata* (1 photos with 1 seeds from 1 sp.), *Ursus thibetanus* (58 photos with 140 seeds from 5 spp.), and *Cervus nippon* (13 photos with 74 seeds from 6 spp.). We identified at least eight epizoochorous plants. There was a positive correlation between the body weight of the mammal and the frequency of photos with epizoochorous seeds, number of epizoochorous plant species, and the average number of epizoochorous seeds in a photo (Spearman's rank correlation, frequency: $\rho = 0.83$, $P = 0.015$, number of species: $\rho = 0.71$, $P = 0.048$, number of seeds: $\rho = 0.85$, $P = 0.007$). Most epizoochorous plants were dispersed by several mammal species and *C. crispus* was the dominant seed disperser for epizoochorous plants, followed by *U. thibetanus* and *S. scrofa*, in terms of number of plant species and seeds dispersed. More quantitative information on external seed dispersal by terrestrial mammals will become available with a wider application of camera trap technique in the future.

S Constraints for population genetic variation via dispersal in a concrete jungle

Anusha Krishnan & Renee M. Borges

Plants in urban concrete jungles are necessary for mitigating pollution and heat island effects and supporting urban fauna. Such plants have two origins: as remnants of earlier vegetation that existed before the city grew around them, or as fresh transplants from nurseries, originating from regions near or far away from the city. The health of such plant populations depends on their genetic diversity, and in turn, on their origins. However, in most cities, little is known about either the origins or genetic diversity of urban plants. In southern India, the cluster fig, *Ficus racemosa*, is a keystone fruit-bearing urban tree commonly found in city temples and parks. Due to their religious significance, these trees are seldom cut, and most have either germinated in situ or been specifically planted. We used 12 microsatellite markers to examine the population genetic structure of *F. racemosa* trees in Bangalore, southern India. Although no evidence of inbreeding (mean $F_{IS} = 0.0366$, $P > 0.05$) was evident, we detected a strong spatial genetic structure (SGS) at short distances (< 1 km). We attribute the absence of inbreeding and lack of a heterozygote deficit to long-distance pollen flow via the highly specialized and largely wind-blown fig wasp pollinators. In contrast, the SGS at short distances could be attributed to limited seed movement by frugivores. While *F. racemosa* fruits are consumed by long-distance seed dispersers like the flying fox *Pteropus giganteus*, much of the fruit crop is also consumed by shorter-distance dispersal agents like the

White-cheeked Barbet (*Psilopogon viridis*) and the Indian Palm Squirrel (*Funambulus palmarum*) whose movements are particularly constrained within the urban environment. We elaborate on the constraints for attraction to fruit crops and their successful dispersal and germination within an urban environment, factors with great impact on the population genetic variation of keystone species within a concrete jungle.

P Feeding ecology and Seed Dispersal of the Common Palm Civet (*Paradoxurus hermaphroditus*) in Singapore

Fung Tze Kwan, N. Sivasothi & Peter Kee Lin Ng

The Common Palm Civet *Paradoxurus hermaphroditus* has been regarded as a potentially important seed disperser in tropical forests. However, systematic studies to examine their diet and ecological role in forest ecosystems are few. In Singapore, a highly urbanised tropical city state, a historical loss of forests and large mammal seed dispersers has resulted in a slow recovery of degraded forests. One of the few remaining native frugivorous mammalian species is the Common Palm Civet. A year round diet study through scat analysis (N = 482) indicated that this species is omnivorous and highly frugivorous, with no distinct temporal variation in its diet. They feed on a diversity of fruit species (N = 41) and defecate intact seeds that are viable. Results from gut passage time experiments and seed germination trials, together with the first use of the GPS telemetry to examine movement patterns of this species estimated a mean seed dispersal distance of 216 ± 46 m, up to a maximum possible distance of 1353 m. Our study showed that the Common Palm Civet, a common yet neglected species, can play an important ecological role as an effective seed disperser, providing medium to long distance seed dispersal services for plant species, including that of large-seeded plants and rare plant species. Furthermore, as a disturbance tolerant species, common palm civets can live in a diversity of habitats and cross urban landscapes, facilitating natural seed dispersal in degraded land where connectivity of green cover may be low. With deforestation and urbanisation in Southeast Asia, this overlooked seed dispersal service provided by the common palm civet becomes increasingly important and relevant to forest regeneration, especially on degraded landscapes.

S The role of seed disperser macro- and micro-biomes and chemicals on the seed dispersal loop

Charles Kwit, M.T. Patton, C.N. Miller, C.L. Lash & S.R. Whitehead

How seed dispersers contribute to the fitness of populations of plants they disperse has served as a unifying theme in the field of seed dispersal ecology. Spatial aspects of seed deposition patterns have been shown to directly influence seed and seedling demography, with much of the evidence here related to dispersal to favorable microsites. In addition, the role dispersers play in deterring seed mortality from vertebrates and microbes through physical pulp removal has been documented. However, one area that has only recently begun to attract attention is how seed disperser-imparted chemicals and macro- and micro-biomes can contribute to seed and seedling fate. We review evidence for these new focal areas, and provide a rationale for systems where such interactions are likely, including myrmecochory (seed dispersal by ants), seed dispersal by bats, and secondary seed dispersal by rodents. This direct connection to the quality of seed treatment by seed dispersers carries ramifications for seed dispersal effectiveness through direct impacts on seed demography. The results also challenge established views on trade-offs between seed disperser attractiveness and seed defense, and may finally establish links between seed treatment by dispersers and plant life history stages beyond the seed.

P Myrmecochory in the Brazilian Caatinga and its response to anthropogenic disturbance and climate change

Inara Roberta Leal, Fernanda M. P. Oliveira & Marcelo Tabarelli

The Caatinga is the largest and most diverse seasonal dry tropical forest. However, it is the third most-threatened Brazilian ecosystem, due to the historical unsustainable exploitation of natural resources, such as firewood collection, overgrazing by livestock and exploitation of non-timber forest products, i.e. chronic anthropogenic disturbance. Caatinga is also menaced by climate change (particularly, an increase in aridity) which may even intensify the negative effects of chronic disturbance. Here we summarize the effects of increasing chronic disturbance and aridity on myrmecochory in Caatinga. Myrmecochory is one of the most important seed dispersal types in Caatinga, with more than 100 plant species from the Euphorbiaceae family having diaspores that are specialized for dispersal by ants. Myrmecochory is strongly associated with small plant stature, suggesting that the primary benefit to plants concerns distance of dispersal, which reduces parental and sibling competition. Increasing chronic disturbance and aridity negatively affect the interaction between high-quality seed dispersers and diaspores, decreasing seed removal and dispersal distance in disturbed and arid sites. Despite high overall ant diversity there is very limited functional redundancy in disperser ant species, resulting in low disperser resilience in relation to increasing disturbance and aridity. This is likely to have important implications for recruitment by myrmecochorous plants, and therefore on vegetation composition and structure, at sites subject to high anthropogenic disturbance and increased aridity.

S Past and future extinctions shape the body size - fruit size relationship between palms and mammalian frugivores

Junying Lim, Jens-Christian Svenning, Bastian Gödel, Søren Faurby & W. Daniel Kissling

The dispersal of seeds by mammalian frugivores influences the structure and composition of many ecosystems, but most ecosystems have undergone defaunation over thousands of years, a process that continues today. Understanding how past defaunation has affected fruit-frugivore interactions will provide insights into how ecosystems may respond to future frugivore loss. However, the degree to which natural ecosystems have responded to past extinctions (i.e., the global loss of megafauna at the end of the Pleistocene) is unclear, and the magnitude of future impact that present-day ecosystems face remains largely unexplored at the global scale. By integrating palm and mammalian frugivore trait and occurrence data worldwide, we reveal a global positive relationship between fruit size and body size of frugivore assemblages. Global variation in fruit size is better explained by present-day frugivore assemblages compared to those of the Late Pleistocene (including extinct species), suggesting a substantial ecological and evolutionary reorganization after Pleistocene mammal extinctions. Interestingly, the reverse is true for the Neotropics where some large-fruited palm species may have persisted over thousands of years following extinction of their main seed dispersers. Using probabilistic simulations of frugivore extinction, we predict that the magnitude of assemblage-level fruit size change necessary to keep up with frugivore loss to be up to five-fold higher than published rate estimates of seed size change following defaunation. Overall, our results suggest that while some large-fruited palms may persist after the loss of their main dispersers, many may be unable to keep pace with future defaunation through evolutionary changes in fruit size alone, and that the brunt of the impact of defaunation (extinction) will probably be disproportionately borne by large-fruited palms, possibly over thousands of years to come.

S **Fruiting phenology and food availability for the Belum Tropical Rainforest Community**

Vivienne Loke Pei Wen, Lisa Ong, Kim McConkey, Param bin Pura, Husin a/l Sudin, Mohamad Tauhid bin Tunil (Cherang), Rizuan bin Angah, Loo Yenyi, Tan Wei Harn, Alicia Solana-Mena, Hii Ning, & Ahimsa Campos-Arceiz

Plants and animals exhibit reciprocal adaptations. Their vital ecological functions are maintained by mutualistic interactions such as seed dispersal, whereby plants provide valuable food resources and animals transport seeds to suitable locations for establishment. Available fruiting phenology is geographically variable and particularly complex in Sundaic forests, where trees often follow complex and unpredictable mast fruiting episodes. To understand the fruiting trends and resource availability for animals in a Sundaic rainforest, we identified fruits edible to different animal groups with the inclusion of local ecological knowledge (LEK) from forest-dwelling indigenous people (locally known as Orang Asli). We monitored the fruiting phenology of the Royal Belum State Park (1245 km², northern Peninsular Malaysia) over 15 months along six 1-km transects, 1.5-m wide through raked-ground surveys; capturing fruiting episodes in a very strong El Niño years (2015–2016) and weak La Niña years (2016–2018). We detected different fruiting trends for fruits typically consumed by different animal groups. Overall, fruit availability for large terrestrial animals is much lower in both diversity and abundance than for smaller frugivores. During the lean period, less than 20 individual fruiting trees per month were available for most animal taxa over the 6-km transect, several of which had low numbers of fruits per m² of canopy shadow. Seasonal fluctuations in abundance can influence the density and functional diversity of frugivores that can be supported within a community, as well as the extent to which they can rely on fruit as a food supply. Our work highlights the very low fruit resources available to frugivores in masting dipterocarp forests, which can have consequences for seed dispersal processes.

S **The forgotten fauna: native seed predators on islands**

Kim McConkey, Jo Carpenter, Janet Wilmshurst, Julian Hume, Debra Wotton, Aaron Shiels & Donald Drake

Human colonisation of islands has resulted in the loss of many native species, and invasion by exotic species, producing novel faunas. The impacts of these changes on mutualistic plant-animal interaction networks have received considerable attention, but the potential effects on some antagonistic interactions, such as seed predation, are less thoroughly understood. Using datasets and examples from three iconic island groups—New Zealand, Hawai'i, and the Mascarenes—we compare the taxonomic and functional diversity of pre-human and contemporary vertebrate seed predator faunas. These archipelagos each once supported between 17 and 24 species of avian seed predators spread across 2 to 4 orders, nearly all of which are now extinct or rare. In comparison, the contemporary seed predator faunas are comprised of between 13 and 24 species, dominated by exotic granivorous birds, and several introduced mammals. Whereas most of the introduced birds have functional traits that are broadly comparable to those of the lost natives, the mammals are more generalist omnivores that may be truly novel in their ability to destroy a wide range of seeds. We highlight the need to 1) understand how these altered seed predator communities have affected plant populations, and 2) determine the extent to which seed predation by mammals is truly novel with respect to the range of plant species and populations affected. More broadly, we argue that negative interactions are an integral part of any ecosystem, and must be acknowledged as such if we are to achieve more holistic restoration frameworks for insular ecosystems.

T Is there a seed dispersal crisis in Europe?

Sara Beatriz Marques Mendes, Catherine J. O'Connor, Jens M. Olesen & Ruben H. Heleno

Seed dispersal is a key ecosystem service with important consequences for plant regeneration, vegetation dynamics and ultimately influencing long-term plant species survival. The current habitat fragmentation and wave of defaunation that Europe faces has raised concerns over the capacity of animals to secure effective seed dispersal, potentially triggering extinction cascades. Even though the ongoing pollination crisis has raised considerable public recognition, the consequences of a potential seed dispersal crisis remains poorly explored. We tackled this knowledge gap by reconstructing the first European-wide seed dispersal network and by evaluating the conservation status of all known seed dispersers. An extensive literature review was conducted in order to extract all records of potential and confirmed seed dispersal records by European animals. Overall, the European seed dispersal network is very diverse, including over 500 plant species and more than 100 species of seed dispersers. The main seed dispersers are common birds and mammals with stable populations. Although our preliminary results suggest that seed dispersal services are not threatened in the near future, we also found considerable knowledge gaps regarding some animal guilds and some countries/regions. Moreover, although seed dispersal publications at a community level have grown considerably during the last two decades, most information still comes from species-focused studies, which hindered broad comparisons. Studies of seed dispersal at a community level are still much needed in Europe, particularly given the importance of seed dispersers in assisting plant redistribution in the face of changing climate.

S Temporal dynamics of seed-dispersal networks mediated by plant phenology in a Mediterranean scrubland

Irene Mendoza & Pedro Jordano

Seed dispersal by frugivores implies that interacting organisms have a matching phenology, i.e. the time of fruiting needs to be concordant with the presence of the frugivorous animal. A frequently-used approach to explore seed dispersal is through complex network analysis, in which species are represented as nodes and interactions as edges. However, seed-dispersal networks are frequently assumed to be constant through time. This static approach obviously ignores the temporal dynamics of seed dispersal that is given by the variable abundance of both fruit crops and frugivorous species. This work uses a multilayer network approach to deal with temporal dynamics of seed-dispersal networks, with an explicit focus on plant phenology. An advantage of multilayer networks is that they distinguish intra-layer (a time span) and inter-layer connectivity (species persistence across time spans), allowing a proper analysis of highly dynamic temporal systems. We aim at assessing how seasonal and long-term phenological shifts in the abundance of frugivores and plant resources will alter seed-dispersal networks. We use as a study system a Mediterranean scrubland community from SW Spain (Doñana National Park). Bird-fruit networks were sampled every 15 days during two consecutive years in the 80's (1981-1982) and recently (2019). Our results show that seasonal fruit phenology is a strong determinant of plant-fruit interactions, with more events of seed dispersal during the peak of fruit production, i.e. September to November. Also, some pairs of species interactions were prevalent among layers, meaning that they have a strong influence in the network structure. These results highlight the sensitivity of fruit-bird interactions to the phenology of interacting organisms and the likely presence of mismatches under a climate-change context that affects the timing of life cycles.

S Epizoochorous dispersal of emerging alien cactus species: *Cylindropuntia pallida* F.M. Knuth, in the arid areas of South Africa

Thabiso M. Mokotjomela, Trevor M. Xivuri & Tshamaano Nemurangon

The emerging cactus species, *Cylindropuntia pallida* (Thistle cholla), native to Northern Mexico has been recorded in arid areas of Northern Cape Province, South Africa. Detected multiple populations of *C. pallida* display high invasion potential with propagule dispersal mediated by the predominant ungulates exploiting the invaded grazing land. For containment of invasion problems, eradication by chemical spraying (Garlon* 480 EC herbicide) has been applied across 16 populations located in different areas. This chemical spraying method substantially (95%) suppresses the population. The aim of the study was to determine the role of movement ecology in managing eradication processes where *C. pallida* populations are treated with chemical foliar spray method. We document the dispersal vectors using photographic and material evidence such as the faecal samples of the vertebrates foraging in the habitat. The local livestock numbers and their daily movement patterns were determined. To infer relative success of clearing, we also compared the levels of *C. pallida* infestation before and after clearing through determining population structure. Results showed that ungulates are major dispersal vectors of *C. pallida* and account for 70% of the movement of the recorded seedlings in two major study sites: Maphiniki and Barkley West. Domestic ungulates provided directed dispersal services displayed by high density of *C. pallida* seedlings around water courses and livestock kraals. Clearing success varied significantly between the study sites: 86% and 58% in Maphiniki and Barkley West respectively. It is recommended that movement patterns of the domestic livestock should be included in the *C. pallida* eradication planning process since ungulates are the major drivers of the species re-infestation in Barkley West.

S Evolutionarily distinct interactions, seed-dispersal networks and landscape fragmentation in a hotspot of biodiversity

Erison Carlos dos Santos Monteiro, Carine Emer & Marco A. Pizo

A persistent challenge in evolutionary biology is to understand how evolution has produced complex webs of interacting species. However, this challenge has become harder in a constantly changing world impacted by human activities. Here we combined phylogenetic, landscape and ecological network tools to understand how forest fragmentation affects evolutionarily distinct interactions and, in turn, how the remaining interactions may influence the robustness of tropical avian seed-dispersal networks. We selected 23 studies designed to record seed-dispersal interactions in the Atlantic Forest of Brazil, We built the phylogenetic tree of the plant and bird species at the regional level to further prune the Evolutionary Distinctness (ED) of each species and by summing the ED of interacting species we found the Evolutionary Distinctness of interactions held by each community. We tested the total EDi per community against habitat percentage, as well as the relationship between EDi and network robustness. We found a total of 176 plant species and 202 frugivorous bird species performing 28,849 interactions. Forest cover negatively affected the cumulative EDi per community. Seed-dispersal networks with higher EDi showed higher robustness to secondary extinctions when plant species were removed from the networks while no significant trend was detected when bird species went extinct first in our simulations. Our findings suggest that forest cover and high EDi are important to avoid network collapse, and consequently co-extinctions in tropical forest fragments.



Food for thought: effects of personality on seed dispersal in modified landscapes

Alessio Mortelliti, Allison Brehm & Sara Boone

Many plants rely on animals for seed dispersal, but are all individuals equally effective at dispersing seeds? If not, then the loss of certain individual dispersers from populations could have cascading effects on ecosystems. Despite the importance of seed dispersal for forest ecosystems, variation among individual dispersers and whether land-use change interferes with this process remains untested. To contribute to filling this knowledge gap, we designed a large-scale field experiment conducted on small mammal seed dispersers. We focus on individual personality in small mammals (e.g., the level of boldness/timidness and anxiety of individuals) because it encapsulates an individual's unique way of behaving and responding to life's challenges, such as the challenge of collecting and maintaining seed caches. Through a field experiment conducted in Maine (USA), we measured personality in 648 individuals belonging to three small mammal species and living in three forest types: including two sites in unmanaged forest, two sites in even-aged forest and two sites in shelterwood forest. We tracked the dispersal of several hundred seeds by these same individuals. By fitting mixed effects models linking personality traits and seed dispersal data, we found that an individual's personality has critical consequences on all key stages of the seed dispersal process. For example, we found that bolder mice and voles tend to select larger seeds; docile voles tend to cache them in optimal germination sites and less anxious voles disperse seeds further from the mother tree than more anxious ones. We also show that anthropogenic habitat modifications shift the distribution of personalities within a population by increasing the proportion of bold, active, and anxious individuals, and in-turn affect the potential survival and dispersal of seeds. We demonstrate that preserving diverse personality types within a population is critical for maintaining the key ecosystem function of seed dispersal.



Fruit consumption of lantana (*Lantana camara*), bugweed (*Solanum mauritianum*), syringa (*Melia azedarach*) and cochineal prickly pear (*Opuntia monacantha*) by exotic and indigenous southern African ungulates

Lindelwa S. Msweli, Christophe Baltzinger, Manqoba Zungu & Colleen T. Downs

Animal visitation to fruiting plants and fruit removal are fundamental for fruit consumption which may potentially lead to seed dispersal. Endozoochorous seed dispersal has been extensively documented showing avian species as main vectors; however, some studies have investigated prominent mammalian species such as bats, primates and ungulates. Nonetheless, the representation of mammalian alien invasive plant (AIP) seed dispersal is poorly documented, particularly in African savannahs, as not much research has been conducted documenting ungulates foraging and dispersing fleshy-fruited AIPs. Our aim was to determine the plant-animal interaction between exotic and indigenous southern African ungulates and fleshy-fruited AIPs: lantana (*Lantana camara*), bugweed (*Solanum mauritianum*), syringa (*Melia azedarach*), and cochineal prickly-pear (*Opuntia monacantha*). In this study, we used camera trapping and field assessments of fruit consumption by ungulates for 21 consecutive days in three sites (1) to determine the community of potential ungulate seed vectors for these AIPs and (2) to determine daily foraging activity patterns and behavioural patterns that may affect seed dispersal effectiveness. Generalised linear mixed effects models were used for the analyses. Mostly, wild ungulates, both perissodactyls (zebra) and artiodactyls (giraffe, warthog, bushbuck, impala, greater kudu, nyala, grey duiker, and wildebeest) fed on the fleshy-fruited AIPs; however domestic ungulates such as cattle also fed on the fleshy-fruited AIPs. Giraffe had the highest visitation frequency, followed by bushbuck. The giraffe did not have a specific time of foraging, with the foraging times observed from early hours of the morning to late evening. The results also showed that ungulates either performed as intentional dispersers (feeding selectively for AIP fruits) or unintentional dispersers (accidentally feeding on AIP fruits while browsing). Overall, this study shows the potential role of ungulates in long-distance dispersal of AIPs which may be responsible for the spread of AIPs in African savannas.

O Even small seeds need large seed dispersers

Miyabi Nakabayashi & Eyen Khoo

Recently, the effect of the loss of large-bodied frugivores is becoming the center of attention in tropical rainforests. It is very clear that large-bodied frugivores play essential roles in seed dispersal of large-seeded plants, but so far little attention is paid to small-seeded plants. Small seeds such as figs can be dispersed by almost all animals that feed on them. However, several species bear large figs (> 10 cm in diameter) with thick flesh. Small-bodied animals feed on these figs, but they usually leave the seeds untouched. Therefore, these figs may depend on large-bodied animals to disperse their small seeds. In this study, we compared fig species density and fig size in three types of forest in Sabah, Malaysian Borneo; old-growth forest, heavily logged young forest, half-empty forest, which lacks large-bodied frugivores. We also compared the density of large-seeded plants such as *Durio* spp. in old-growth forest and half-empty forest. The fig species density in old-growth forest was higher than that in half-empty forest, but there were no significant differences between old-growth forest and heavily logged young forest. Differences in the fig size showed the same tendency. Similarly, the density of *Durio* spp. in old-growth forest was higher than that in half-empty forest. Our results indicate that defaunation of large-bodied animals may have a negative effect on seed dispersal of small-seeded plants as well as large-seeded plants. Figs are the keystone food resources for tropical animal species especially when other foods are scarce. Therefore, reduction in population and species density would directly affect the number of animals in tropical rainforests. More efforts are needed on the effect of defaunation on seed dispersal systems of small-seeded plants besides large-seeded ones.

S Phenology as a driver of local and long-distance seed dispersal by animals

Shoji Naoe

Phenology, such as the timing of bird migration and fruiting, is one of the important factors driving ecosystems. However, the effects of phenology on seed dispersal by animals are still understudied. In this presentation, I introduce our studies showing the strong effect of phenology on 1) local and 2) long-distance seed dispersal. 1) We investigated how fruit abundance affects seed dispersal of six bird-dispersed plants which share frugivorous birds but have different fruiting seasons in a Japanese temperate forest (Naoe et al 2018 American Journal of Botany). Inter-annual and inter-seasonal variation in community-level fruit abundance determined both fruit removal and the seed dispersal distance across species, but the effect differed with seasonal changes in bird behavior. Abundant fruit satiated fruit removal by birds only during fruit-feeding periods, not during insect-feeding periods. A scarcity of fruit increased the dispersal distance, but only during the migratory period. 2) By using the oxygen isotope ratio of seed, we evaluated the long-distance vertical seed dispersal of summer-fruiting cherry and autumn-fruiting kiwi by mammals in Kanto Mountains (Naoe et al 2016 Current Biology; 2019 Scientific Reports). The results were contrasting: while seeds of cherry were dispersed toward mountain tops, seeds of kiwi were dispersed toward the foot of mountains. These were probably because mammals followed plant phenology in temperate zone which proceeds from the foot to the top of mountains in spring to summer and from the top to the foot in autumn to winter (Figure). This implies that many of temperate animal-dispersed plants which fruit in autumn and/or winter may not be able to sufficiently escape from current global warming. Our results suggest that studying how phenology affects seed dispersal is essential to understand the difference in seed dispersal patterns among plants and years, and to predict future plant distributions under climate change.



A global review of frugivory and seed dispersal on islands

Manuel Nogales, Kim McConkey, Tomás A. Carlo, Debra Wotton, Peter Bellingham, Anna Traveset, Aarón González-Castro, Ruben Heleno, Kenta Watanabe, Haruko Ando & Donald Drake

The information on frugivory and seed dispersal on islands is widely spread and patchy, strongly depending on the topics and islands concerned. A systematic literature search on islands was performed using Internet scientific search engines, avoiding isolated territories with very large areas (e.g. Great Britain, Madagascar, Japan, New Guinea, etc.). About 450 contributions were recorded and most of the knowledge was focused on New Zealand (25%), the Canaries (19%) and Puerto Rico (12%), which were the better-studied islands. A great gap in the number of studies was detectable in Pacific archipelagos near Asia and Australia, and in general in the Indian Ocean. Most of these studies were carried out during the last two decades and especially throughout the last one. Due to the relative simplicity of island environments, such places are ideal to develop interesting and original ecological and evolutionary ideas. Therefore, further deep studies concerning seed dispersal effectiveness, non-standard mechanisms of dissemination or complete ecological networks would be ideal for these limited territories. From a conservation perspective, the introduction of invasive species is often considered as the first threat factor for island organisms (both animals and plants). Therefore, it is really important to know how the native systems work and at the same time to evaluate how alien species alter the natural order of interactions. This information is essential for the restoration of original environments. To the best of our knowledge, this is the first review carried out at a global scale, covering frugivory and seed dispersal on islands.

P Effect of disturbance on mutualistic networks of fruit bats in a tropical rainforest

Laura Obando-Cabrera & Oscar Murillo

Mutualistic interaction networks between plants and their dispersers have an important role in the regeneration and succession of tropical forests. However, this capacity can be affected by environmental transformation. This work studied the effect of anthropogenic perturbation on the structure and robustness of mutualistic networks between frugivorous bats and plants in a humid tropical forest in the Colombian Choco Biogeographic region. A disturbed and a non-disturbed area were sampled, and we recorded the interactions between bats and plants by analyzing the seeds present in bat faecal samples. Both areas showed considerable differences in species composition. Bats of the genus *Platyrrhinus* were found exclusively in the non-perturbed area, while species from genera such as *Artibeus*, *Carollia* or *Sturnira*, were associated with the perturbed area. The interaction networks had a heterogeneous distribution, where bats were generalists while plants were specialists. No nestedness or modularity was found as expected from other mutualistic network studies. Furthermore, no differences in robustness were found, thanks to the plasticity of some species. In conclusion, habitat perturbation affected the composition of specialist species but not the core of generalist species, and therefore the networks did not present significant changes in their structure and robustness between perturbed and non-perturbed areas.

S Seed dispersal network of a megafauna-rich tropical Southeast Asian rainforest

Lisa Ong, Kim McConkey, Param bin Pura, Husin a/l Sudin, Mohamad Tauhid bin Tunil (Cherang), Nurul Ain binti Amirrudin, Lily Ong & Ahimsa Campos-Arceiz.

We explore the seed dispersal system of a Malaysian tropical rainforest with megafauna and high diversity of frugivores. We used local indigenous knowledge in combination with field observations and published records to assemble qualitative networks comprising multiple plant and animal taxa to emulate three different seed dispersal scenarios. Our analysis found all networks to be nested and modular, indicating distinct functionalities between different animal groups. Most animals are specialist seed dispersers. Our primary network, describing endozoochorous interactions, reflects relatively high robustness to extinctions. Siamang (*Symphalangus syndactylus*), gibbons (*Hylobates* spp.), Asian elephants (*Elephas maximus*), sun bears (*Helarctos malayanus*), langurs (*Presbytis siamensis*, *Trachypithecus obscurus*), and hornbills (Bucerotidae) are animals important to the functioning of the seed dispersal network. Amongst plants, *Ficus* species stood out as the only generalist plants with high links and species strength, acting also as network connectors. Simulating defaunation, we see network stability upheld by a diverse animal community. Despite not matching the seed-dispersal influence of larger vertebrates, small-bodied animals especially birds and rodents are the last strong-holds of the seed dispersal network. Their loss results in high magnitudes of changes in shrinking networks. The functionality of a species is often lost before a species is threatened. Urgent efforts are required to conserve both seed-dispersal interactions as well as the knowledge of indigenous communities pivotal for our understanding of the natural world.

S Patterns of tree regeneration in degraded rainforest fragments suggest declines in seed dispersal and a role for ecological restoration

Anand M. Osuri, Divya Mudappa & T. R. Shankar Raman

The majority of Earth's remaining tropical forests occur in human-modified landscapes and are increasingly exposed to pervasive disturbances such as forest loss, edge effects, timber extraction, and hunting. These disturbances can impact natural regeneration and the trajectory of tree communities by disrupting animal-mediated processes such as seed dispersal, and by altering abiotic conditions such as light and soil nutrients. We examined the effects of forest loss on tree regeneration, using plot data from contiguous rainforests and rainforest fragments (≤ 32 ha) interspersed among tea and coffee plantations in the Western Ghats, India. We found that while overall sapling density and diversity did not differ between fragmented and contiguous forests, the density and diversity of old-growth species—many of which depend on large animals for seed dispersal—was around 50% lower in fragments. Moreover, fragments had substantially fewer 'immigrant' saplings (presumed dispersed into sites as conspecific adults were absent nearby)—most notably among old-growth species dispersed by birds, which declined 79% in fragments compared to contiguous forests. Consistent with the reduction in seed dispersal, sapling diversity correlated more strongly with the diversity of adult trees locally in fragments than in contiguous forests, such that areas within fragments having species-poor overstories had poorer regeneration than areas having species-rich overstories. Collectively, these findings highlight that reductions in animal seed dispersal could limit the ability of tree communities in degraded rainforest fragments to recover spontaneously from disturbance. We discuss the potential role of ecological restoration in overcoming dispersal and other barriers to natural regeneration in fragmented rainforests, drawing on our experiences and the preliminary findings of ongoing research from an ecological restoration experiment in the Western Ghats.

O How much do birds contribute to restoration areas?

Natalia Paes, Wesley Silva, Fernanda Ribeiro da Silva & Paulo Antônio de Almeida Sinisgalli

Ecosystem services are nature's contributions that directly or indirectly affect human well-being. Birds are among the agents that provide ecosystem services, such as seed dispersal. Seed dispersal is an essential process in the plant life cycle, which in tropical areas occurs mainly among plants exhibiting the zoochorous syndrome. Currently, the Atlantic Forest has been reduced to 11.9% of its original coverage, and requires concerted efforts in ecological restoration for the recovery of this biome. Plant recovery should not be viewed as the only goal in ecological restoration, but also the restoration of the ecological interactions that can lead the ecosystem to a state close to its original condition. Recent studies have shown that birds contribute to the ecosystem restoration process by mediating seed dispersal, even in abandoned fields. The approach of ecosystem services brings to light the link between ecological and economic sciences, where the valuation of ecological economics can contribute to the understanding, mensuration and development of economic tools applied for biodiversity conservation and development of public policy. This study offers a pioneer approach, reconciling analysis of ecological interactions of seed-dispersing birds with plants in restoration areas, using mutualism networks metrics, combined with an ecological-economics valuation of these services using the Production Function method. The study was conducted in three restored areas located in the cities of Santa Bárbara d'Oeste, Cosmópolis and Iracemópolis, in São Paulo state. The mutualism network metrics were used to develop an equation based on the economic value of replacement costs, and estimated on the restoration costs for the study areas. The results showed that the monetary values varied between US\$ 13 to 317.64. This research demonstrates that network metrics capture the most important information about the ecological interactions, and enable replication of the study while considering essential ecological aspects of the ecosystems.

S The effects of variation in seed crop size and phenology and dispersal kernels of seeds and seedlings in montane old-growth forests

Mario B. Pesendorfer, Frederik Sachser, Ursula Nopp-Mayr & Georg Gratzner

For trees with synzoochory or diplochory, variation in the extent and timing of seed drop can have strong effects on dispersal outcomes because of the demographic and behavioral responses of seed predators and dispersers. Masting, the synchronous production of intermittent bumper crops in plant populations, is thought to result in reduced proportional seed predation (predator satiation hypothesis) and increased dispersal rates by food-hoarding animals (predator dispersal hypothesis). In montane forests, however, not only the annual variation in the extent, but also the phenology of the seed drop may drive seed fate, as population responses and diplochory by rodents may be affected by the first snowfall. Here, we use a long-term data set on seed drop and seedling establishment dynamics in an old-growth montane forest in the central Alps to investigate how extent and timing of peak crops affect dispersal in *Fagus sylvatica*, *Abies alba*, and *Picea abies*. Using an inverse modeling approach, we assess the effect of crop size and phenology on seed and seedling dispersal kernels, as well as their differences. Preliminary results suggest complex interactions among various drivers of seed fate and provide little support for the predator satiation and dispersal hypotheses. The weak support for hypothesized ultimate drivers of mast-seeding raises the question whether the strategy is the consequence of selection or simply an emergent property of abiotic and biotic mechanisms underlying seed production and seed fate.

O Do big players matter in seed dispersal networks?

Soumya Prasad, David Westcott & R. Sukumar

It has been proposed that megafauna provide unique seed dispersal services that are poorly compensated by other frugivores. Across the tropics, the abundance and ranges of large frugivores has declined in historical times. Community-wide characterization of seed dispersal at sites harboring an intact fauna is essential to evaluate the role of megafauna in dispersal, examine fruit-frugivore associations and assess the vulnerability of plant communities to disperser declines and climate change. Dispersal modes were inventoried for 92% and fruit traits for 84% of the 73 woody plant species occurring in a tropical dry forest community at Mudumalai, southern India. Fruit-frugivore interactions were examined using tree watches, camera traps, and faecal samples. To evaluate the different definitions for "large" and "megafaunal" frugivores, we compared dispersal services provided by animals weighing < 1 kg, between 1-44 kg, between 44-1000 kg and > 1000 kg. We documented fifty-five vertebrates dispersing seeds of 34 plant species, across > 1500 interactions leading to 257 plant-disperser links within the community. There was high variation in interaction frequencies. Although 72% of the links and 69% of the interactions were by animals weighing < 1 kg, the larger frugivore groups had a higher "degree". There was low overlap in fruit diets between the largest frugivore taxa at our site (i.e., deer, bear and elephants), although each group overlapped with smaller frugivores. The intermediate sized frugivores (1-44 kg), which mostly comprised of herbivorous mammals, displayed distinct associations with fruit traits, and had more specialized interactions compared to smaller or larger fauna. The decline of herbivorous mammals across Asia has not received the kind of conservation attention that megafauna attract in the region. Our results iterate that we need to assess vulnerabilities and redundancies to ensure that we invest in conserving critical limiting ecosystem service providers, especially in the context of land use and climate change.

P **Feeding habits of the great hornbill (*Buceros bicornis*) in Kaiga, Uttarakannada, southern Western Ghats, India**

K. Puttaraju & Bhanusri S. P

Kaiga region is popularly known as a breeding site for the Great Hornbill, which is the largest among Asian Hornbills. Being a flagship species, their presence and status reflect the health of the forest ecosystem by carrying out seed dispersal and pest control. Kaiga village—where four units of Kaiga Nuclear power plant are commissioned—is a rich source of biodiversity and the protected area acts as cornerstones of biodiversity conservation providing vital ecosystem services. We studied the feeding and breeding biology of the Great Hornbill in the Kaiga forest by monitoring four nests from mid-February to May in 2017 and 2018. The nesting period lasted an average of 90 days and observations at the nest revealed the pre- and post hatching phases to be 40 and 45 days, respectively. Over this period for both years, a total of 3112 food items were delivered by the male hornbill to the inmates, composed of 4 species of lipid-rich, 6 species of sugar-rich fruits, and 11 kinds of animal matter. Great Hornbills are able to store about 100 fruits per feeding in the esophagus and stomach, and then regurgitate their seeds (seed size between 5 and 20 mm) as they move, making hornbills significant seed dispersal agents. Seed Dispersal is by way of regurgitation or defecation of ingested seeds. The female Great Hornbill loses only some feathers during the incubation period and they fly out of their nests for foraging after the eggs hatch, unlike the belief that they lose all of their feathers and the complete responsibility of feeding the family is on the male. Understanding the nesting and feeding biology of hornbills is important because of the crucial role they play in the forest ecosystem. Documentation, conservation, and management of Great hornbills have become an international priority because of its ecological, economical, and social significance.

S **Super-generalist species in ecological networks: the role of biological traits in individual interactions**

Elena Quintero & Pedro Jordano

Complex ecological networks are built through a diverse set of interactions between plants and animals. These processes influence the functioning and composition of communities in ecosystems, where super-generalist species have a pivotal role, acting as hubs within these networks by providing support to a diverse array of partners. Using as a model the lentisc (*Pistacia lentiscus*, Anacardiaceae), a super-generalist plant species that dominates the Mediterranean shrubland, we aim to explore the configuration and characteristic features of its interaction network with animal partners that influence its natural regeneration. *Pistacia lentiscus* can be considered as a foundation species, since it provides abundant fruit food resources to a wide array of resident and migratory birds, being at a central position in the structure of Mediterranean lowland shrubland plant-frugivore interaction networks. Many avian species rely heavily on the fleshy fruits of lentisc during autumn and winter, especially migrant species that need to maintain or gain body mass to continue their migration or the over-winter stay (e.g. *Sylvia atricapilla*, *S. melanocephala*, *Erithacus rubecula*). Most avian species act as mutualistic dispersers for the plant, however lentisc fruits are also heavily consumed by other species such the wasp *Megastigmus pistaciae*, rodents or granivorous birds (*Chloris chloris*) that act as antagonists. In this study we illustrate a preliminary, individual-based, interaction network for 40 individuals of *P. lentiscus* with their avian partners, based on data from video-recordings combined with DNA barcoding and direct observations for the identification of avian visitors. By using exponential random graph models (ERGMs) we explore individual plant traits that potentially determine the mode of mutualistic and antagonistic interactions. The ultimate aim of this study is to understand *Pistacia lentiscus*' super-generalist strategy from an intra-individual variation perspective, looking at interaction patterns of individual plants and their consequences for seed dispersal success.

T **The role of avian frugivores in the germination of keystone *Ficus* species in KwaZulu-Natal, South Africa**

Islamiat Abidemi Raji, Vuyisile Thabethe & Colleen T. Downs

Ficus species provide key components of the fruit resources that sustain numerous frugivorous avian and mammalian communities in many parts of the world. Avian frugivores serve as seed dispersers of various *Ficus* species. Furthermore, their gut passage may influence seed germination. We examined the effect of ingestion and gut passage of birds on different species of *Ficus* fruit. *Ficus* fruits were fed to selected bird species and seed retention time recorded. Seeds were extracted from the excreta of individual birds at the end of each feeding trail and planted in different trays with potting soils (no additives), placed in a greenhouse and monitored daily for germination. Germination rate and germination success were recorded and compared with that of non-ingested depulped seeds, as well as that of seeds in whole fruits. Ingested *Ficus natalensis* and *F. lutea* seeds germinated faster for Red-winged Starlings *Onychognathus morio* and Common Bulbuls *Pycnonotus barbatus* than the non-ingested seeds and whole fruits. However, whole fruit germinated faster than depulped. The result of this study is expected to show the roles birds play in dispersal, regeneration, and maintenance of plant community through keystone *Ficus* species. Research, feeding and germination trials are still ongoing on other birds and *Ficus* species.

P **Smallest nocturnal primates facilitate seed germination and seedling growth in rainforests**

Veronarindra Ramananjato, Zafimahery Rakotomalala, Camille DeSisto, Daniel S. Park, Nancia N. Raelinjanakolona, Nicola Guthrie, Zo E. S. Fenosa, Steig E. Johnson & Onja H. Razafindratsima

Fruit-eating animals often play important roles as seed dispersal agents in many ecosystems, particularly in tropical regions. Yet, the extent to which seed dispersal by omnivorous nocturnal animals may facilitate the germination and recruitment of plant communities is poorly investigated. Characterizing their roles in seed dispersal could provide a more complete picture of how animal-mediated seed dispersal ecology influences tropical forest ecosystem functioning. Here, we investigated the dispersal service of two species of omnivorous nocturnal lemur species (*Microcebus rufus* and *M. jollyae*) in Madagascar's southeastern rainforests. We collected data on dispersal events by sampling seeds from faecal materials of live-trapped individuals, and conducted germination trials with defecated seeds compared to manually extracted seeds from fresh fruits (control). Data show that the two species can have significant contributions as seed dispersers as they defecated a large proportion of seeds from 23 plant species from various forest strata, and 83.33% of the defecated plant species germinated and produced viable seedlings. In addition, defecated seeds germinated faster than control seeds with a significantly high germination rate and seedling length. Although the two lemur species dispersed both native and non-native plant species, non-native species represent only a small proportion (17.19%) of the defecated seeds. These results suggest that omnivorous animals can act as important seed dispersers, which may have critical implications for forest regeneration and diversity maintenance. These findings also add to the limited information on the ecological contribution of omnivorous nocturnal animals in the functioning of tropical rainforests. Finally, this work provides important insights to promote conservation of mouse lemurs and other taxa associated with them.

S Dispersal by native frugivores affects management of an invasive plant species
Geetha Ramaswami, Soumya Prasad, Monica Kaushik, David Westcott, Raman Sukumar & Suhel Quader

Fleshy-fruited invasive plant species can rapidly infiltrate existing plant-frugivore interactions by forming associations with generalist frugivores, often leading to altered dispersal patterns of native and invasive seeds. We investigated the seed-dispersal of a widespread, fleshy-fruited invasive plant, *Lantana camara*, in two protected areas by native avian frugivores. In Rajaji Tiger Reserve, we assessed the role of frugivore movement in seed dispersal distances and inferred that managed areas are always within re-seeding distances from source plants. In the Rishi Valley Bird Preserve, on the other hand, we found little evidence of negative impacts of *L. camara* on native plant-frugivore networks and on fruit removal from heterospecific native species fruiting concurrently with *L. camara*. We recommend that effective management of *L. camara* cannot be achieved without considering dispersal of invasive seeds by native frugivores.

S Impact of habitat fragmentation on plant-frugivore mutualistic networks
Nancia Raelinjanakolona & Onja Razafindratsima

Mutualistic interactions are vital for maintaining biodiversity and ecosystem stability. Increasing habitat degradation can put such interactions at a high risk of disruption, threatening the survival and persistence of both interacting species. We examined how the structure of plant-frugivore (birds and lemurs) networks may be affected by edge effects in fragmented habitats. We collected field data on plant-frugivore interactions through direct tree observations and by using camera-traps attached on canopies of fruiting trees in forest edge and interior habitats in the rainforests of the Complex Torotorofotsy-Ihofa, in the eastern part of Madagascar. We focused on 18 plant species and recorded the identity and behaviour of all birds and lemurs visiting the trees. Habitat fragmentation affects the structure of plant-frugivore networks by changing the composition of interacting species. There were more interactions in forest edge vs interior overall, and the observed patterns in the forest edge were mostly driven by interactions of plants with small-sized frugivores. Larger frugivores were only observed in the interior. These network patterns could have serious impacts on the diversity and structure of plant communities and their conservation in the edge habitats. Given the diverse frugivory networks at forest edges, there is an urgent need to focus more on conservation actions toward edges to ensure the continuation of the interactions of such disturbed habitats.

P The resilient frugivorous fauna of a degraded forest fragment and its potential role in the enrichment of vegetation

Eduardo Delgado Brites Rigacci & Wesley Rodrigues Silva

Anthropocentric defaunation affects critical ecosystem services such as seed dispersal, putting at risk ecosystems and biomes. Although the ecological redundancy present in complex systems such as rainforests can amortize the functional losses caused by defaunation, studies using fruit-fed feeders to induce ecological redundancy, in order to enrich and recover, natural environments are rare. Thus, our objective in this study was to evaluate the residual fauna with potential for the enrichment of a semideciduous seasonal forest fragment with native plant species. A total of 36 sampling points was selected at the Mata Santa Genebra fragment, with feeders installed at different heights that were monitored by camera-traps. Variable amounts of native fruits of zoochorous species were offered alternately in the feeders. Based on more than 36,000 hours of records, *Turdus leucomelas*, *Sapajus nigritus*, and *Salvator merianae* were the species that ingested the highest fruit richness. *Didelphis albiventris* was the most frequent visitor but defleshed most of the fruits. The frugivorous avifauna, were "effective" dispersers, with a high rate of visits and the consumption of a large quantity of fruits, while an inverse relationship was found for mammals. These differences are related to the behavior expected for each taxon concerning fruit defleshing, which is more prominent in frugivorous mammals than frugivorous birds. We showed that an increase in the diversity of frugivores leads to a higher chance of effective visitation, and the explanation is based on the classic relationship between biodiversity and ecosystem function. Finally, with this study we can highlight the importance of the use of fruit-enriched feeders and their potential to attract resilient frugivores, by using their seed dispersal services for local floristic enrichment.

O Frugivores' morphological and chemical interaction niches relationship: It is not what it looks like

A. Tobias Nicolas Rojas, Román Ruggera & Pedro G. Blendinger

Consumption of fruits by frugivores could direct the evolution of particular combinations of fruit traits. While frugivores use morphological and chemical fruit traits as cues to make foraging decisions, it is known that both types of traits are found to be vaguely related in fruits. Interaction niches (INs), or the multivariate space constructed with the traits of interaction partners, is a promising tool to test the relationship strength among fruit traits in the diet. To understand how morphological and chemical IN relate, we constructed IN for morphological and chemical traits using seed-dispersal networks. We i) estimated the relationship between INs via co-inertia analysis and ii) originality (distance from community centroid) and uniqueness (distance to closest neighbor) for each niche centroid to evaluate the relationship of these measures with specialization (d') and number of interaction partners; iii) we fitted a GLM to test the relationship between estimated dispersion of INs with specialization (d') and number of partners; iv) we used two null models to evaluate departures from frequency of interactions and number of species used by frugivores. We found an important difference when comparing co-inertia of morphological and chemical fruit traits ($RV = 0.3$) with co-inertia of morphological and chemical frugivores INs ($RV = 0.7$). Chemical and morphological originality were negatively related with the number of interaction partners ($b = -0.5$; $b = -0.4$, respectively). IN dispersions were positively related with the number of interaction partners ($b = 0.6$, morphological; $b = 0.6$ chemical). Comparison of null models suggest that frequency of interactions and number of partners are the main shapers of the observed patterns. Our results show that the number of partners determines the amplitude and position of the centroid of the IN and that fruit trait relationships are unlikely to be strengthened by frugivore foraging decisions. In summary, frugivores consume a combination of fruit traits similar to the community centroid, this usage of different food elements could fit with the diet complementarity mechanism.

S Temporal Dynamics of plant-frugivore networks in the tropical wet forests of Hispaniola Spencer C. Schubert & Eric L. Walters

Seed dispersal mutualisms play a central role in structuring plant and animal communities in tropical forests. Aseasonal climatic conditions in tropical environments allow year-round flower and fruit production with widely variable phenological patterns. The continuous turnover and abundance of fruit resources across time and space drive movements and feeding behavior of frugivores. Yet, how this spatiotemporal complexity shapes the plasticity (i.e. ‘rewiring’) of species interactions remains poorly understood. To investigate the consequences of seasonal change on the species composition and interaction patterns, we sampled local communities at six sites in the central Dominican Republic continuously over an annual period (May 2018–May 2019). We quantified the abundance of all avian and fleshy fruit taxa along transect grids at each 25 ha study site every 14–21 days. We sampled the attendance and feeding interactions of frugivorous birds through focal observations of all plant taxa encountered with ripe fruits on each visit. We recorded frugivory involving 44 avian and 53 plant taxa. The mutualistic dependence of the plant assemblage was highly skewed toward a core set of three endemic avian taxa, which accounted for 78% (N = 7,691) of interactions. The composition of networks was driven by the local abundance of resource and consumer taxa, which were highly heterogeneous across the study region. Moreover, by explicitly accounting for the temporal changes in bird and fruit resource abundance at the local scale, the number of mutualist partners was related positively with the period over which birds and ripe fruits are present in the system. Our results demonstrate the importance of phenology in determining species roles within plant-frugivore networks and reinforce the how phenology may mediate competition and facilitation dynamics within plant and frugivore assemblages.

P Artificial perches as a technique for enhancing tropical forest restoration Spencer C. Schubert & Eric L. Walters

Recovering secondary forests on degraded agricultural lands represents a promising opportunity to offset global carbon emissions as well as increasing local biodiversity and ecosystem services that forests provide. In the insular tropical forests of the Caribbean, frugivorous birds are the primary seed dispersers for most native woody plants and likely have a large influence on regeneration dynamics during the early stages of succession. In 2017, we initiated an experimental forest restoration program incorporating artificial perches on private farms within the Rio Yaque del Norte watershed in La Vega province, Dominican Republic. Five restoration plots (0.15–0.25 ha) were constructed in pastures along deforested drainage ways. In each plot, 6–12 artificial perches, each 5 m in height, were constructed from bamboo poles fitted with crossbars. We remotely monitored perch use by birds using video cameras and evaluated the effects of perches on the establishment of woody plants in seedling quadrats with manipulations of ground layer treatments (e.g. grass removal) both below perches and in open spaces. Ten avian species were recorded visiting perches, with the most common being Northern Mockingbird (*Mimus polyglottos*), Smooth-billed Ani (*Crotophaga ani*), and Gray Kingbird (*Tyrannus dominicensis*). Perches had a statistically significant effect on seedling recruitment 12 months post-installment. By comparing the results with data collected from plots beneath the canopy of isolated trees, we identified canopy cover as an important factor in facilitating seedling recruitment. We conclude that artificial perches are an effective method for augmenting the natural seed bank but are likely to be most effective when used in tandem with planting trees (or “live stakes”) that readily grow to produce shade and litter.

S Intrinsic and extrinsic drivers of intraspecific variation in seed dispersal are diverse and pervasive

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There is a growing realization that intraspecific variation in seed dispersal can have important ecological and evolutionary consequences. However, we do not have a good understanding of the drivers or causes of intraspecific variation in dispersal, how strong an effect these drivers have, and how widespread they are across dispersal modes. As a first step to developing a better understanding, we present a broad, but not exhaustive, review of what is known about the drivers of intraspecific variation in seed dispersal, and what remains uncertain. We start by decomposing “drivers of intraspecific variation in seed dispersal” into intrinsic drivers (i.e., variation in traits of individual plants) and extrinsic drivers (i.e., variation in ecological context). For intrinsic traits, we further decompose intraspecific variation into variation among individuals and variation of trait values within individuals. We then review our understanding of the major intrinsic and extrinsic drivers of intraspecific variation in seed dispersal, with an emphasis on variation among individuals. Crop size is the best supported and best understood intrinsic driver of variation across dispersal modes; overall, more seeds are dispersed as more seeds are produced, even in cases where per seed dispersal rates decline. Fruit/seed size is the second most widely studied intrinsic driver, and is also relevant to a broad range of seed dispersal modes. Remaining intrinsic drivers are poorly understood, and range from effects that are probably widespread, such as plant height, to drivers that are most likely sporadic, such as fruit or seed color polymorphism. Primary extrinsic drivers of variation in seed dispersal include local environmental conditions and habitat structure, including fruiting neighborhood. Finally, we discuss the complexities involved in understanding the evolutionary and fitness consequences of intraspecific variation in seed dispersal.

S Frugivory by macaques across varying levels of anthropogenic interference

Asmita Sengupta

Provisioning of non-human primates (primates henceforth) is a socio-cultural tradition across South and Southeast Asia. Human provisioning of primates may occur directly by hand-outs or inadvertently when supplies of discarded human food are accessible to primates at garbage dumps or in the form of crops in agricultural fields. The rhesus macaque *Macaca mulatta* is categorized as a ‘weed’ macaque due to its dependence on ‘human activities for a substantial portion of their diet.’ However, studies have shown that certain populations of rhesus macaques are highly frugivorous and are effective seed dispersers for many plant species. I examined how fruit consumption and the diversity of fruit species included in the diet of rhesus macaques varied across groups with differing levels of dependence on anthropogenic food resources. To this end, I made observations on three groups of rhesus macaques - one completely dependent upon natural resources (Group 1), one provisioned by tourists for a part of a year (Group 2) and one consuming crops in addition to natural foods across the year at the Buxa Tiger Reserve (Group 3), West Bengal, India. We found that fruits made up 75% of the diet of Group 1 whereas they constituted only 26% of the diet of Group 3. While Group 2 consumed very little natural fruit in the tourist season, their fruit consumption was comparable to that of Group 1 when the Reserve was closed to tourists. The diversity of fruits included in the diet was also the highest for Group 1, followed by Groups 3 and 2. We suggest that it is essential to reduce provisioning and to plant macaque-preferred fruiting species at the forest-agricultural land ecotone to ensure that the macaques continue to consume natural fruits and reliably disperse the seeds of a wide gamut of plant species in the Anthropocene.

T Feeding biology of invasive rose-ringed parakeets *Psittacula krameri* in urban landscapes of eThekweni Metropole, KwaZulu-Natal Province, South Africa

Tinyiko Cavin Shivambu, Ndivhuwo Shivambu & Colleen T. Downs

The Rose-ringed Parakeet *Psittacula krameri* is one of the common urban bird species that has established feral population outside its native range through the pet trade. It has invaded ~ 35 countries including South Africa. We studied the feeding biology of rose-ringed parakeets between September 2018-2019 in Durban metropolitan areas, eThekweni Municipality, KwaZulu-Natal Province, where this bird has established. We determined the distribution of rose-ringed parakeets feeding sites, land use cover types, and the type of food they consumed across the seasons. We also investigated which birds communally feed with rose-ringed parakeets. About 60 feeding sites were established and all were distributed in urban populated areas. Fruits and flowers of 31 species including native and alien trees were consumed by parakeets with fleshy fruit making ~ 58% of the diet followed by flowers (~ 23%), and the remainder. Tree species such as *Croton sylvaticus*, *Ficus burkei*, *Jacaranda mimosifolia*, and *Sterculia africana* contributed most to parakeet's diet across the seasons. Seven bird species including *Acridotheres tristis*, *Colius striatus*, and *Melaenornis pammelaina* were found to occasionally feed with parakeets. Understanding the feeding biology of rose-ringed parakeets contributes to understanding the impacts associated with the species should it increase its invasive distribution range in South Africa.

P Role of small mammals in seed dispersal, predation and germination: A review

Manpreet Singh

Small mammals like squirrels, civets, bats, tree shrews etc. play important roles in tropical forests by providing seed mediated services/disservices. Mutualistic relationships exist among fruiting tree species and small mammals in which fruiting trees gain benefit by achieving reproductive success and associated small mammal species gain benefit by consuming fruits, which are a major component of diets of frugivorous mammals. However, some small mammals provide disservices as well through pre-dispersal predation of seeds. Seed predation can significantly reduce the population number of particular fruiting species. Small mammals play their role in seed germination by breaking the hard endocarps of seeds by mechanical disintegration or through alteration of chemical constituents of seeds by fluids present in their digestive tract. Post-dispersal seed fate and seedling establishment can determine the population dynamics of fruiting tree species in forest ecosystems as well as the forest community structure. Thus, seed dispersal, predation, and germination influence the complex mosaic of interactions between forest trees and their corresponding animal mutualists that govern the ecosystem dynamics. An attempt has been made to understand the role of small mammals in each of these three processes for which literature is reviewed for tabulating the taxa with their corresponding mutualist plant species. Scientific gaps have been identified and directions have been given for future research in this field, which may help in adding knowledge to our current understanding of relationships between small mammals and tropical fruiting trees in the context of seed related processes. An attempt has also been made to see which small mammals play roles in long distance dispersal of seeds by conducting a meta-analysis of dispersal distances by different small mammal species.

The body weight and skull measurements predict seed dispersal capacity in bat, primate and carnivore species.

Elise Sivault, Anthony Herrel, Pierre-Michel Forget, Anne-Claire Fabre & François Bretagnolle

Zoochory is an essential plant-animal interaction in tropical forests. Among the large number of animals using this process, mammals are well studied and very effective for seed dispersal. Indeed, some species disperse seeds over long distances by swallowing and defecating them (endozoochory). In order to get an idea of what skull and body characteristics can tell us about seed dispersal, we studied three orders: Chiroptera, Primates, and Carnivora, from South America, Asia, Africa, and Madagascar. This study involved the analyses of skull measurement data and ingested and dispersed seed and fruit sizes. Furthermore, it required data on seed dispersal distances and digestion times for all species studied (N = 104). Our data revealed that body weight provides significant information on the ingestion capacities of frugivorous mammals. Moreover, the weight seems to be an adequate indicator to predict the seed dispersal distances produced by Primates. In addition, according to the skulls of museum specimens, the distance between the molars and the length and opening of the jaw are the most predictive morphological measurements of the size of the seeds that can be ingested. Many of these species are threatened in tropical forests. Therefore, it is crucial to predict the contribution of past and present mammal species for different processes in plant recruitment and thus in the regeneration of tropical forests.

Elephant frugivory and wildboar seed predation of *Irvingia malayana*, a large-fruited tree, in a rainforest of Peninsular Malaysia.

Alicia Solana Mena, Lisa Ong (main author), Kim McConkey & Ahimsa Campos Arceiz

Irvingia malayana is a large-fruited and large-seeded tree species of Southeast Asia. As a large-fruited tree, it interacts with large mammal consumers, which either disperse or consume its seeds. In this preliminary study, we describe functional differences between Asian elephants (*Elephas maximus*) and wild boars (*Sus scrofa*) in their interactions with the fruits of *I. malayana* in a rainforest in northern Peninsular Malaysia. We baited one camera trap under each of five fruiting *I. malayana* trees for a total of 86 camera trap nights and recorded a total of 145 independent visits from 12 vertebrate species. We recorded only two (1.4% of 145) visits by elephants, but they were the only animals to swallow *I. malayana* seeds (1.9% of 312 focal seeds). Wild boars were frequently recorded (29.7% of the animal visits), and they often acted as seed predators (consuming 24.4% of the 312 focal seeds). Besides these functional differences, an interesting temporal resource differentiation between the two species was also observed. Elephants consumed fresh fruits of one or two days old, while wild boars consumed fruits older than five days, probably when seeds could be accessed more efficiently. No animal species other than elephants was recorded to swallow the fruits of *I. malayana*, suggesting that elephants may be important dispersal vectors for this tree species in the tropical rainforest of Malaysia.

O Interpretation of the role of frugivores in seed germination potential dependent on study design

Simon D. Stringer, Russell A. Hill, Lourens Swanepoel, Sarah E. Dalrymple, Bibi Linden & Nicola F. Koyama

Frugivory and seed dispersal contribute to the maintenance and regeneration of plant communities through transportation of seeds and enhancing germination through seed processing mechanisms. The effects of frugivore seed processing mechanisms on seed germination are well studied and the potential benefits include disinhibition (pulp removal), scarification (gut passage), and fertilisation (from faecal matrix). Nevertheless, our review found that there is a bias in the comparative treatments included in seed dispersal studies, through exclusion of entire fruit control groups and the fertiliser effect. In this study, we aimed to address such biases by using ecologically relevant experiments to investigate the influence of seed processing mechanisms on germination probability and latency of three locally abundant plant species, common in the diet of samango monkeys (*Cercopithecus albogularis schwarzi*), and who are seed-spitters (disinhibition) and seed-swallowers (gut-passage and fertiliser effects). We designed experiments to isolate the cumulative effects of seed processing mechanisms and tested the effects of five treatments and one control treatment (entire fruit). We further assessed if exclusion of ecologically relevant seed treatments or relevant controls would affect our interpretation of the impact of the disperser on seed germination. Comparing gut passage and disinhibition indicated negative effects, whereas comparing gut passage and entire fruit controls indicated neutral effects in one species. Compared to gut passage alone, the fertiliser effects indicated positive or neutral benefits on germination probability. Our study demonstrates that the impacts of frugivores on germination may be under- or over-estimated in ecological literature where relevant treatments and meaningful controls are excluded.

S Natural seed dispersal can promote diversity in grassland restorations when safe sites are available.

Lauren L. Sullivan & Haldre Rogers

In the United States, much of the native grassland has been converted to agriculture. Restoration recreates grasslands on the landscape, but evidence suggests that these restorations tend to have lower diversity than native grasslands, and lose forb diversity through time. Seed dispersal can play a key role in increasing species richness and promoting forb diversity, as this process brings new propagules into the restored systems. However, the role of natural seed dispersal is often overlooked, and can be altered by factors such as the distance to a source population, herbivore presence, and the presence of “safe sites” that have reduced competition. We conducted an experiment to determine the conditions that promote successful natural seed dispersal and increase restoration diversity and forb cover. In 2012, we planted core populations of high species diversity surrounded by low diversity. Within each plot we had paired 10 m transects, one seeded during the restoration, and the other covered with plastic during the initial seeding. We removed the plastic in 2014, which allowed these transects to be colonized naturally from surrounding plant species into “safe sites” that have reduced competition. Additionally, half of the blocks were fenced to reduce herbivore pressure. In 2019, we sampled plant species cover in plots directly adjacent to, and 10 m away from, the high diversity cores. We found species movement from the cores was highest in plots nearest to the core and in “safe site” plots. Additionally, we found that grass to forb ratios, regardless of where the species originated, were lowest in “safe site” plots— indicating that natural species dispersal, as opposed to traditional management practices, promotes a higher proportion of forbs. These results indicate that dispersal plays a critical role in restored grasslands and promotes desired restoration outcomes, but only when competition is reduced and source populations are close.

Leaf-cutting ants as a key sink for seeds and seedlings in neotropical human-modified landscapes

Marcelo Tabarelli, Rainer Wirth, & Inara Roberta Leal

Leaf-cutting ants (LCA) have been considered mega-herbivores operating across a wide range of neotropical ecosystems, from grasslands to tropical forests. In addition to leaf material, these ants collect substantial amounts of fruits/seeds from woody plant species to be used as substrate for fungus-growing in underground nest chambers. LCA collect fruits on the ground but also those still attached to parental plants, including large trees. Moreover, some LCA species are proliferating in human-modified landscapes, thus amplifying their impacts as seed dispersers/predators and their role as key drivers of seedling recruitment and vegetation regeneration. A review of the literature suggest that: (1) LCA collect fruits/seeds from numerous plant species from local floras and thousands of seeds can be collected from targeted species through a single plant reproductive season, and (2) LCA-mediated dispersal services include seed cleaning, seed removal and deposition far from parents, as well as seed deposition at suitable sites for germination, such as external nest refuse dumps. The negative scenario is less well studied: several LCA species discard seeds in refuse chambers inside the nests. Moreover, LCA usually defoliate seedlings growing around nests, including those which emerged from seeds deposited or unintentionally dropped by the ants during harvesting operations. Recent evidence from the Caatinga dry forest indicates that even those seedlings recruiting far from the nests but inside vast foraging areas can be defoliated and killed by the ants. As LCA continue to proliferate across human-modified landscapes they can potentially alter patterns of vegetation regeneration and ecosystem resilience by operating as a sink for seeds and seedlings. This perspective reinforces the role played by LCA as ecosystem engineers across the Neotropics and opens a broad research avenue connecting global changes, seed dispersal/frugivory and ecosystem dynamics.

Morphological and nutritional characteristics of Japanese crowberries that are used by Japanese black bears.

Kaori Takahashi, Taiga Amari, Moe Ide, Kosuke Saeki, Yutaro Koide, Kengo Kawamoto & Kazuaki Takahashi

The Japanese black bear feeds on the fruits of various fleshy-fruited plant species and fulfils key seed dispersal functions. Although no evidence had hitherto been presented regarding whether they feed on the berries of four ericaceous dwarf shrub species (Japanese crowberry *Empetrum nigrum* var. *japonicum*, *Gaultheria pyrolloides*, *Vaccinium uliginosum* var. *japonicum*, and *Vaccinium vitis-idaea*) that are widely distributed in alpine regions, we have found that they consume copious amounts of Japanese crowberry's berries in an alpine zone of Mt. Asama (2568 m asl) in central Japan. We assessed the morphological and nutritional characteristics of the berries. Fruits were collected (approximately 400 g fresh weight per species) from >100 randomly selected colonies at various locations and altitudes within the 100 m × 700 m study plot in an alpine zone of Mt. Asama between September and October 2017. Of these, 30 randomly selected fruits of each species were used to measure size (longest and shortest diameter), fresh weight, and dry weight of each fruit and seed. Selected fruits (approximately 270 g per species in fresh weight) were used to measure the nutritional characteristics including crude protein, crude fat, nitrogen-free extract, crude fiber, crude ash, polyphenol, total ascorbic acid, and refractometric Brix degree as a sugar content index. The cost-benefit ratio of morphological fruit attractiveness (i.e., fresh pulp weight and dry pulp weight divided by total fresh seed weight per fruit) of Japanese crowberry was significantly lower than those of *G. pyrolloides* and *V. vitis-idaea*. Crude protein, crude fat, and nitrogen-free extract levels were lowest while fiber content was highest in Japanese crowberries. Therefore, black bears selected these berries despite them being morphologically and nutritionally inferior to the fruits of the other three shrub species. The bears seem to make up for the nutritional deficit by consuming large quantities of these berries.

T Vertical seed dispersal of Japanese crowberry by Japanese black bears and birds: estimation using stable oxygen isotope ratios.

Kazuaki Takahashi, Shoji Naoe, Kosuke Saeki, Yutaro Koide, Taiga Amari, Yoshihiro Tsunamoto, Ichiro Taysu, Takashi F. Haraguchi & Kaori Takahashi

Mountain ecosystems, including alpine and subalpine zones, are exceptionally fragile and particularly vulnerable to global climate change. If the average temperature rises 2 degrees, isothermal lines will rise approximately 300 meters. Thus, the resilience of alpine plants to the temperature rise may be affected by vertical seed dispersal and whether seeds are transported to higher altitudes where the temperature will be favorable for alpine plants. We estimated the potential of Japanese Black Bears *Ursus thibetanus japonicus* and birds to disperse seeds of Japanese crowberry (*Empetrum nigrum* var. *japonicum*) to higher altitudes by measuring the stable oxygen isotope ratio of seeds. Our study was conducted in an alpine zone of Mt. Asama (2568 m asl) in central Japan. A study transect of approximately 100 m × 2500 m was established between 1670 m and 2370 m asl. With every 100 m of elevation, study plots were established in the study transect, and two seed traps were set at each study plot. Bear scats and bird droppings were collected from the study transect and the 18 seed traps, respectively, twice a month between July and November 2017. We used the negative correlation between altitude and the stable oxygen isotope ratios of non-dispersed seeds that was calculated using reference seeds collected directly from fruiting shrubs with approximately every 50 m of elevation on the calibration line. We estimated altitudes of the parent shrubs, by substituting the stable oxygen isotope ratio of seeds within bear scats or bird droppings in the calibration line. The coefficient of determination r^2 of the calibration line was 0.48. In total, 13 bear scats and 9 bird droppings with seeds of Japanese crowberry were collected between 1663 m and 1836 m asl and between 1720 m and 1870 m asl, respectively. Mean vertical seed dispersal distance by bears was longer than that by birds, and bears dispersed seeds to higher altitudes.

○ Long-term monitoring of seed dispersal by Asian elephants in a Sundaland rainforest

Tan Wei Harn; Adeline Hii, Alicia Solana-Mena, Ee Phin Wong, Vivienne Loke, Ange S. L. Tan, Anders Kromann-Clausen, Ning Hii, Param bin Pura, Muhamad Tauhid bin Tunil, Sudin A/L Din & Ahimsa Campos-Arceiz

Asian elephants *Elephas maximus* inhabited almost all forests in tropical Asia until recently, yet their importance in forest ecology has received much less attention than that of African elephants *Loxodonta* spp.. The tropical rainforests of the Sundaic region are peculiar in their phenology, with supra-annual and highly irregular episodes of mast fruiting. Here we present a long-term (73-month) monitoring of the seeds dispersed by elephants in dipterocarp forests of northern Peninsular Malaysia. We conducted monthly dung surveys in two mineral licks 11.3 km apart frequently visited by elephants. Additionally, we recorded haphazard observations of seeds and seedlings in elephant dung. We recorded a minimum of 45 morphospecies from at least 25 plant families dispersed by elephants. Elephant seed dispersal was very heterogeneous in space, with only 40% of the morphospecies dispersed at both sites (Jaccard dissimilarity index = 0.42). Temporally, elephants dispersed seeds in sporadic pulses of abundance and diversity, without any apparent seasonality—seeds appeared in 19.8 % of 1,341 dung piles and 56.2 % of 73 months sampled. Over half (56%) of the plants dispersed by elephants fit within the concept of megafaunal dispersal syndrome, suggesting a higher level of diverse elephant-plant seed dispersal interactions than previously assumed in Asia. We actually propose an expansion of the megafaunal dispersal syndrome to include plants with large fruits and an intermediate number ($5 < x < 100$) of large seeds (e.g. *Durio* and *Artocarpus*). As the natural range of Asian elephants continues to contract, this will have profound and long-term consequences for their function.

S Ingestion by an invasive parakeet species reduces germination success of invasive alien plants relative to ingestion by indigenous turaco species in South Africa

Vuyisile Thabethe, Amy-Leigh Wilson, Lorinda A. Hart & Colleen T. Downs

Avian frugivores play a key role in seed dispersal of many plant species, including invasive alien plants. We assessed the effect of gut passage on the germination of selected invasive alien plant species in South Africa. Fruits of four fleshy-fruited invasive alien plant species: *Solanum mauritianum*, *Cinnamomum camphora*, *Psidium guajava* and *Morus alba*, were fed to two species of indigenous turacos—Knysna Turaco *Tauraco corythaix* and Purple-crested Turaco *Gallirex porphyreolophus*, and to invasive Rose-ringed Parakeets *Psittacula krameri*. Seed retention time was determined as this can influence both seed dispersal and germination success. Germination success of ingested seeds was compared with that of manually de-pulped seeds, as well as to seeds in whole fruit. The germination success of seeds of all the invasive plant species increased significantly after ingestion by both turaco species compared with seeds from whole fruits. Germination success of manually de-pulped seeds did not differ significantly from that of turaco ingested seeds. In contrast, seed passage through the digestive tract of rose-ringed parakeets significantly reduced germination success and viability of ingested invasive plant species. Our results suggest that Knysna and Purple-crested turacos are legitimate seed dispersers of fleshy-fruited invasive plants, while Rose-ringed Parakeets are mainly seed predators. Although seed predation by Rose-ringed Parakeets negatively affects the reproductive success of these plants, it is unlikely that this will suppress the spread of these invasive alien plants in South Africa as they are already well established. Furthermore, they can facilitate dispersal by seed regurgitation and dropping uneaten fruits away from the parent plant. Similar trends could be expected for indigenous seeds that Rose-ringed Parakeets feed on and therefore these birds remain a negative influence within invaded ecosystems.

S Strategic planning of rewilding of avian seed dispersers at different spatial scales

Hugo Thierry, Ethan Rose & Haldre Rogers

Alarming extinction rates have led to the degradation of ecosystems around the world through the extirpation of key ecological functions. Rewilding has emerged as an approach aiming in restoring these extirpated functions through the introduction of locally-extinct or analogous species. While most efforts focus on the long-term survival of introduced species, little focus is done on aiming to optimize functional restoration spatially across the ecosystems, which is essential for the ecological success of such ambitious projects. We use the island of Guam as an ongoing example of a potential rewilding project, which has seen all its native seed dispersers functionally or completely extirpated by the invasive Brown Tree Snake *Boiga irregularis*. The absence of seed dispersers is linked to reductions in species diversity and changes in native forest structure, as well as slowed regeneration of degraded forest. Stakeholders aim in rewilding the island with the Micronesian Starling *Aplonis opaca*, an effective seed disperser with a remnant population still on the island, and the Mariana Fruit-dove *Ptilinopus roseicapilla*. Using the case study, we illustrate two complementary approaches: (i) the “Spatial planning of rewilding efforts’ (SPORE) framework, a large scale spatially-explicit model to identify effective management scenarios for functional restoration; and (ii) the “Estimating Seed-Animal-Landscape Interactions” model, an individual-based model simulating different bird species within theoretical landscapes to identify small-scale strategies for rewilding. These approaches underline the need for adapting rewilding strategies to integrate various key factors such as management constraints and landscape configuration in order to maximize functional restoration and thus success of these projects.

Difference of deposition site quality among frugivorous mammals in vertebrate seed dispersal Kahoko Tochigi, Sam Steyaert, Tomoko Naganuma, Akino Inagaki, Koji Yamzaki & Shinsuke Koike

Seed dispersal is a critical process in ecosystems as it affects plant population dynamics and community structure. Many mammalian species are important frugivores and seed dispersers for fruiting plants, but differ in where they deposit seeds due to their species-specific ecological characteristics, such as movement ability and habitat selection. This variable seed deposition will impact seed recruitment and seedling establishment, because of the different environmental conditions seeds are exposed to. To understand the function of each mammalian frugivore species as seed dispersers and, therefore, their significance to plant populations and communities, it is important to evaluate differences in the deposition environments that they exhibit. Our objective was to evaluate differences in the quality of the microhabitat in which the studied frugivore species deposited seeds. We conducted field surveys in a temperate forest ecosystem and collected faeces of five mammal species that are frugivores—Asian Black Bear *Ursus thibetanus*, Japanese Macaque *Macaca fuscata*, Japanese Marten *Martes melampus*, Raccoon Dog *Nyctereutes procyonoides*, and Japanese Badger *Meles anakuma*. We measured environmental factors in the deposition sites of faeces and in typical forest areas as control, and assessed the differences and similarities of these microhabitat factors among each mammalian frugivore species. We found that the microhabitats of deposited site of fleshy fruit species seeds by five frugivore species and the degree of similarity of microhabitat among species varied with species and seasons. These differences and similarities resulted from ecological characteristics of each species, such as behavior and habitat selection. In conclusion, we suggest that the diversity of the dispersal environment is maintained and different plant species can be dispersed successfully, because of the variability in the deposition behaviour of the five frugivore species that inhabit the region.

Individual networks of plant-animal interaction: Insights into spatial structure and influencing factors Jadelys Tonos, Onja Razafindratsima & Amy Dunham

While the role of frugivores in shaping the spatial template of seed fall in many ecosystems is well acknowledged, research on mutualistic networks of plant-frugivore interactions have primarily focused on binary, species-level interactions. Frugivores serve as mobile links between sessile plants, such that examining the network patterns of frugivore visitation between individual plants can inform our understanding of mutualistic interactions in space, with implications for plant community regeneration, structure, and biodiversity. We used direct observations of the movement and foraging of a frugivorous lemur *Eulemur rubriventer* to generate individual networks of frugivore visitation and to better understand factors affecting these patterns of visitation. Results revealed a strongly skewed network structure in which most individual plants remained poorly connected and a small proportion of individuals dominated the network in visitation frequency and connectivity. We found that an individual plant's fruit-crop size, the richness of its fruiting neighborhood and its contribution to landscape spatial connectivity all had significant and positive influences on the plant's network role. These well-connected plants had a positive influence on the visitation of neighbors, and they played an important role in shaping the spatial structure of the visitation networks. Having demonstrated extensive variation in the interactions of animal mutualists with individual plant hosts; the influence of space, individual traits, and plant neighborhoods on this variation; and the role of highly visited plant hubs, our results have important implications for a better understanding of how animals can affect their plant hosts, from plant fitness and population demography to community-scale interactions. Clarifying the mechanisms that shape this variation in the context of frugivory, we can further increase our understanding of patterns in seed dispersal and their influence on plant regeneration, community structure and biodiversity.



Mammal seed-dispersal networks in changing Mediterranean ecosystems

Anna Traveset, Gema Escribano-Avila, Juan Pedro González-Varo, & Jose Maria Fedriani

The Mediterranean region is one of the most complex regions on Earth in terms of geological history, geography, morphology and natural history. It represents a melting pot and meeting ground for species of varying origins, and it is a biodiversity hotspot. The present-day mammal fauna of the Mediterranean basin is only a weak reflection of what it was in the middle and upper Pleistocene times, many of them known to be seed dispersers. In this work we ask the following questions: Which are the plant species in this region that currently depend exclusively or mostly on mammals for their dispersal? Do such species have particular traits that distinguish them from species with a mixed dispersal system? Do plant species that depend upon few mammals (i.e., with lower functional redundancy) have greater chances of a seed dispersal collapse? Through an intensive literature search, we collated information on (1) the plant species that mammals disperse in the Mediterranean basin and (2) the full assemblage of dispersers for each of those plants. We further obtained data on morphological, nutritional, visual fruit traits, plus fruit odor and ripe fruit persistence on the plants, testing for differences between the two groups of plants (totally dependent upon mammals vs mixed dispersal system) by means of multidimensional scaling analysis or NMDS. About a dozen plant species depended mostly on mammals for seed dispersal and 15 mammal species were found to disperse their seeds, the most generalized species being foxes, badgers, stone martens and genets. Plants dispersed only by mammals differed in particular traits from those having mixed seed dispersal. Finally, evidence was found that some plant species depending fully on mammals are suffering from seed dispersal collapse while others seem to have been rescued by either domestic or wild mammals introduced to the region.



Age difference in seed dispersal parameters found in Japanese macaques

Yamato Tsuji, Shintaro Ishizuka, Risma Yanti, Takafumi Suzumura, Atsushi Takizawa & Toshio Hagiwara

Although the ecological effect of intra-specific variability has rarely been taken into account, it has been documented to influence seed dispersal outcomes across almost all frugivores. We used individual-based information on faecal contents of free-ranging Japanese Macaques *Macaca fuscata* to test effects of age class on seed dispersal parameters. The macaques are group-living animals, but it has been known that dietary composition vary among age classes (adult vs juvenile). We therefore predicted that dispersal parameters would be reflected in such age differences. We conducted field work at four different study sites (Kinkazan, Shiga Heights, Shodoshima, and Koshima) in a whole year (May 2018–April 2019). In each study site we collected fresh faecal samples of known individuals, and recorded seeds within them and evaluated 1) percentage of seed appearance, 2) number of seeds per single faeces, 3) percentage of damaged seeds, and 4) seed species richness as seed dispersal parameters. In general, the number of seeds and percentage of damaged seeds within single faeces of adults were greater than those of juveniles, while species richness of the latter was greater than those of the former. Finally, the percentage of seed appearance showed no age-specific difference. Our study highlights that differences in individuals' age class lead to within-group variations in seed dispersal services.

P **Seed dispersal by Japanese macaques inhabiting rural areas in central Japan**
Yamato Tsuji, Hironori Seino & Hiroshi Ebihara

We studied endozoochorous seed dispersal by Japanese Macaques *Macaca fuscata* in Toyokawa City, Aichi Prefecture, Central Japan, where several troops are involved in crop-raiding and conflict with local people. We conducted monthly field surveys between May and September 2019 and collected fresh macaque faeces within their home ranges. We also counted seeds in faeces and identified seed plant species. We identified several thousands of seeds from 8 different plant species in faeces. The species richness dispersed by Toyokawa macaques was much smaller than those in other study sites inhabited by wild populations. The number of seeds and percentage of damaged seeds within single faeces, on the other hand, did not differ between Toyokawa and the wild populations. Beside faecal analysis, we estimated seed dispersal distances between feeding sites and defecation sites based on 1) the location points of radio-collared animals and 2) gut-passage time obtained from captive animals. The estimated seed dispersal distances by Toyokawa macaques were several hundred meters, and maximum dispersal distances reached more than one kilometer, which was the same as those shown by wild populations. This study implies that dependence on rural areas and crops might deteriorate the ecological role of the macaques as seed dispersal agents in forest ecosystems. We will also discuss the effect of pest management on seed dispersal by the macaques.

S **Fruit size matters, but not disperser size: Bat-mediated seed dispersal of *Anthocephalus cadamba* in anthropocene**
Mahandran Valliyappan, Murugan C.M., Chen J. & Nathan P.T.

Certain plants bear fruit with special traits that make them exclusively attractive to nocturnal dispersers rather than diurnal animals, and such a phenomenon is generally known as the 'bat-fruit syndrome'. In this study, we studied a plant (Rubiaceae: *Anthocephalus cadamba*) exhibiting this syndrome, where its fruit placement is away from the main trunk with long stalks that hang free from the foliage, and having fruits with its seeds embedded in a fleshy pulp. Two sympatric fruit bat species (Pteropodidae: *Cynopterus sphinx* and *Pteropus giganteus*) were the frugivore visitors. Based on field observations of frugivory by bats, fruits were categorized into three classes, namely (smaller-unripe, medium-unripe and larger-ripe). Both consumed larger-ripe fruits in situ. The larger bats (*P. giganteus*) had lower gut retention time (< 10 min) and they defecated seeds just beneath the parent tree, whereas the smaller bats (*C. sphinx*) had longer gut retention times (> 30 min), and dispersed seeds farther. Visitation frequency of smaller bats was higher than that of the larger bats, which suggests smaller bats do a better job of seed dispersal. Furthermore, the fruits of three different classes were subjected to quantitative analysis of essential minerals and secondary metabolites. The results suggest that the fruits selected by bats had 6-9x higher levels of essential minerals than that of fruits not-selected by bats. Further, larger-ripe fruits consisted of secondary metabolites in low or undetectable ranges. As predicted, the larger-ripe fruits consisted of more viable seeds than that of the fruits of the other two categories, which were not consumed by bats. The present study suggests that in *A. cadamba*, the fruit size determines the quality of fruits, whereas the disperser size has no role in affecting the quality of seed dispersal.

S Seed dispersal of a native tree is promoted by the invasion of ornithocorous shrubs and modulated by their density

David L. Vergara-Tabares, Pedro G. Blendinger, Agustina Tello, Susana I. Peluc & Paula A. Tecco

Fleshy-fruited invasive plants establish mutualistic interactions with native seed dispersers and may indirectly affect the mutualisms between native partners. Invasive plants may either disrupt native plant dispersion through competition for seed dispersers or promote seed dispersal via the attraction of fruit-eating animals. Moreover, invaders density may modulate the direction and/or magnitude of such effect on native plants. The marked seasonality of fruit availability that characterizes temperate communities may be reduced by invasive plants that fruit asynchronously with natives. This occurs in mountains of central Argentina, where ornithocorous invasive shrubs (*Pyracantha* spp.) fruits in winter, during the fruit scarcity period and consequently fruit-eating bird abundance increases at invaded sites. During autumn, the fructification of the dominant native tree *Lithraea molleoides* overlaps with the beginning of the invaders fruiting period. This allows testing opposite predictions regarding the effects of invasive species on native seed dispersal. We compared fruit consumption by fruit-eating birds on *L. molleoides* during the non-overlapping and the overlapping periods, at six sites with different densities of *Pyracantha* spp. shrubs (high, low and non-invasion). We counted fruit consumption during 2-hours on 15 individuals of *L. molleoides* at each site. A GLMM analysis showed that fruit consumption was significantly related to period ($F_{1, 167} = 10.60$; $P = 0.001$) and invasion density ($F_{2, 167} = 10.33$; $P = 0.005$). Fruit consumption of the native tree increased at invaded sites during the overlapping period. This response was greater at highly invaded sites. The new resource provided by *Pyracantha* seemingly would not disrupt seed dispersion of the dominant native tree. It rather promotes fruit removal by seed dispersers and this effect may be exacerbated with higher densities of these invasive shrubs. We highlight that fruit tracking by birds may be the mechanism responsible for the increment of seed dispersal in sites shared with ornithocorous invasive shrubs.

S The ecological consequences of defaunating complementary frugivore functions

Nacho Villar, Claudia Paz, Leticia Bulascoschi, Paula Akkawi, Tadeu Siqueira, Valesca Zipparro, Fabiano Farah, Carine Emer, Pedro Jordano & Mauro Galetti

Defaunation of large-bodied herbivores from ecosystems has a strong influence on the regulation of ecosystem dynamics. On grassland ecosystems the functional role of large herbivores has been extensively studied, but clearly this is not the case for tropical rainforests. Furthermore, potential synergies and redundancies of different large herbivore types are frequently overlooked. We conducted a long-term multisite landscape-scale exclusion experiment across gradients of defaunation in the hyperdiverse Atlantic Forest of Brazil, where most large herbivores are also frugivores. We examined experimentally how two functionally distinct large generalist mammalian herbivore species (the Lowland Tapir *Tapirus terrestris*, a solitary hypergeneralist browser and seed disperser; and the White-lipped Peccary *Tayassu pecari*, a herding hypergeneralist seed and seedling predator) regulate the structure of diversity, and affect critical aboveground and belowground ecosystem functions. Our results support the notion that these large herbivores indeed play distinct functional roles and affect the dynamics of neotropical rainforests in counter-intuitive ways.

T Exploring the role of *Macaca nemestrina* as seed disperser

Giovanni Villa

Seed dispersal provides a means for plant seeds to escape competition and density-dependent seed predators and pathogens and to colonize new habitats. Ninety percent of all primates found in tropical regions are dependent on the forest; this makes the effectiveness of frugivorous species in the seed dispersal process an important topic. The overall objective of this study is to examine the ecological role of Southern Pig-tailed Macaques *Macaca nemestrina* as seed dispersers at the Segari Melintang Forest Reserve, Perak, Peninsular Malaysia. In demonstrating their role in facilitating forest regeneration in the Segari region, an economic argument for conservation and protection of this threatened primate species can be presented. The study has been conducted on two habituated groups of 40 and 55 individuals, respectively. My protocol includes the identification of food plant species, distances of dispersed plant seeds, assessment of feeding ecology, seed handling strategies and seed fate. To characterize the pattern of dispersion I examine the seed shadow and I investigate the post-dispersal seed fate *in situ* (for dropped or spat seeds) and *ex situ* (for swallowed seeds in faecal samples). I found macaques dispersed seeds via swallowing, spitting and dropping with different fruits and seeds. For most of the fruit species the effect of spitting, swallowing and dropping was positive, as most of the seeds dispersed were intact and within one month the seeds germinated. Furthermore, the pulp firmly attached to the seeds, the hard seed coats that protect the seeds and the cheek pouch of the monkeys, suggest an evolution of traits that leads to an effective dispersion. The seed dispersal service of different individuals within the group altered depending on their sex and age. This proves that pig-tailed macaques are legitimate seed dispersers and confirms the mutualism between plants and pig-tailed macaques. I conclude highlighting the importance of conservation for this Vulnerable species.

S Seed dispersal by fishes in rivers of Central Mexico tropical dry forests

Elisabet V. Wehncke & Vanessa Montes de Oca

Morelos is the main center of cultivation and trade of ornamental freshwater fish, and where exotic species impact natural ecosystems. Although their effects are commonly evaluated as the change in community structure, its potential role as seed dispersers has not been evaluated so far. The Amacuzac River, which crosses a seasonal dry forest of Central Mexico, is home to 11 exotic and 8 native fish species. In 2015–2016 we performed analyses of stomach contents (15–30 specimens/species) and identified seed consumer species. We calculated the number of individuals with seeds and evaluated differences among fish species, seasons (wet and dry), and 7 localities. We classified stomach contents with seeds according to four categories and compared the pattern of seed consumption among fish species, season and locality. We found 4 seed disperser species (73 out of 1408 individuals), of a total of 13 species collected, corresponding to two natives, *Astyanax aeneus* and *Notropis moralesi*, and two exotic species, *Amatitlania nigrofasciata* and *Aequidens rivulatus*. By combining data of two years, we found that 18% of individuals consumed seeds of 26 plant species, from which 10 genera were identified. The Poaceae was the most representative family of seeds found in fish tracts. There was a marked effect of season on both, the number of individuals with seeds and the percentage of seed consumption, the wet season showing the highest values. We did not find significant differences in the number of individuals with seeds between localities or species of fish, but we did so for the percentage of seed consumption. *A. aeneus* and *A. nigrofasciata* were the most frequent seed consumers. In this seasonal riparian environment, the wet season represents the time when fish consume higher numbers of seeds, suggesting it is the time when its dispersal potential is greater.

S Quantifying seed rain patterns in a remnant and a chronosequence of restored tallgrass prairies

Katherine Wynne, & Lauren Sullivan

Seed rain or the dispersal of seeds into an area, is an understudied phenomenon that is closely related to the colonization, establishment, and persistence of species in a community. However, very little is known about natural seed rain patterns in grassland communities. Furthermore, it is virtually unknown how seed rain patterns change during the restoration process and whether these patterns are comparable to remnant systems. Additionally, seed rain studies typically lack replication and standardization. To address these gaps in knowledge, we revisited a seminal grassland seed rain study conducted by Rabinowitz and Rapp (1980) and quantified the seed rain patterns in the same remnant tallgrass prairie and a chronosequence of restoration. In May of 2019, we deployed 200 turf-grass seed carpets (0.1 x 0.1 m) in 3-, 6-, and 15-year-old restored prairies and a remnant prairie. We collected and replaced seed traps every 2 weeks, and identified and counted all seeds collected. From May to August 2019, we collected over 25,000 seeds representing at least 70 species. We found differences in the abundance of seeds falling in restored vs remnant grasslands, and differences along the chronosequence. In general, restored prairies had higher abundances of captured seeds than the remnant. Additionally, we found an inverse relationship between captured seed abundance and age since restoration, where younger restorations had higher abundances of seeds falling. Over the same time interval, we also captured more seeds and species in the remnant prairie in 2019 than Rabinowitz and Rapp did in 1980. Although this study is ongoing, we expect to find differences in species composition and timing of seed dispersal between the remnant and restored prairies varying with restoration age. Overall, our work further informs management efforts on how to better use spatio-temporal patterns of seed dispersal in creating high-quality restorations.

P Pre-dispersal frugivory and seed predation by insects in an invaded plant community

Suann Yang, Evan Burr & Lauren Ellis

Interactions between species play an important role in shaping communities, and plant-consumer interactions are no exception. For plants that are dispersal-limited, insect pre-dispersal frugivores and seed predators can negatively impact seed dispersal by vertebrates, either through damaging fruit pulp or consuming seeds. The magnitude of these impacts could depend on the timing of these interactions with respect to fruiting phenology. For example, plant species with long fruiting phenophases could host multiple generations of insect consumers in a season. However, in the Anthropocene, assemblages of native and non-native species create opportunities for novel interactions to form, and alter their expected impacts. In this study, we characterized the temporal patterns of insect larvae in the fruit and seeds of fleshy-fruited plants for a heavily-invaded, deciduous, secondary successional forest. For 11 plant species, we recorded the phenology of fruiting each week for six months. By collecting ripe fruits each week for dissection, we found Dipteran, Lepidopteran, and Coleopteran larvae in fruit pulp and seeds. We found positive correlations between cumulative frequency of larval presence and length of fruiting period for both non-native ($P = 0.0005$, $\rho = 0.7325$) and native plant species ($P = 0.0005$, $\rho = 0.5869$), suggesting that phenophase length corresponds to oviposition opportunities in both native and non-native species. However, consumer satiation occurs more quickly for non-native plants, because fruit crop sizes are much larger for non-native than native plant species. Also, the peak of larval presence tended to occur before or at the peak of fruit abundance for native plant species, while larvae were found most often in non-native fruits when their fruit abundance was declining in the landscape. We conclude that apparent competition favors non-native plant species in our system, because the negative impacts of pre-dispersal insect consumers are minimized through high plant fecundity and mismatch in phenology.

P Digestive efficiencies of frugivorous birds fed varying concentrations of equicaloric glucose and sucrose artificial fruit diets

Manqoba M. Zungu

Digestive physiology is important for understanding the feeding behaviour of organisms. Specifically, studies on the digestive physiology of frugivorous and nectarivorous birds are important for elucidating their preference patterns in the wild and the selective pressures they exert on fruit pulp and nectar. In this study, digesta transit times and digestive efficiencies of three species of birds, the Cape White-eyes *Zosterops virens*, Red-winged Starlings *Onychognathus morio* and Speckled Mousebirds *Colius striatus* were investigated on equicaloric glucose or sucrose artificial fruit diets. Three concentrations, approximating the natural range of sugar concentrations in sugary, bird-dispersed fruits were used: low (6.6%), medium (12.4%) and high (22%). Digesta transit times of birds increased with an increase in concentration for all diets but were generally higher on glucose diets. Intake rates, on the other hand, decreased with an increase in sugar concentration. All species of birds failed to maintain a constant assimilated energy intake on glucose diets but mousebirds and white-eyes maintained it on sucrose diets. Apparent assimilation efficiencies of glucose diets for all species were comparable and typical of those found in other frugivorous birds. However, assimilation efficiencies for sucrose diets differed widely with red-winged starlings displaying very low assimilation efficiencies and as a consequence; they lost significant body mass on all sucrose diets. These results demonstrate the importance of digestive physiology in explaining fruit selection patterns in frugivorous birds and how a seemingly trivial physiological trait can have dire ecological consequences.



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Christophe Baltzinger	christophe.baltzinger@inrae.fr; INRAE, France	Karimi, Sorour; Shukla, Ushma	Isfahan University of Technology, Iran; INRAE, France	Complementarity of seed dispersal mechanisms mediated by ungulates
Noelle G. Beckman	noelle.beckman@usu.edu; Department of Biology and Ecology Center, Utah State University			Advancing an interdisciplinary framework to study seed dispersal ecology
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Ana Cristina Crestani	aninhacrestani@hotmail.com, ana.crestani@unesp.br; São Paulo State University - UNESP (current)	Mello, Marco Aurelio/Cazetta, Eliana	University of São Paulo/ Santa Cruz State University	Interindividual variations in plant and fruit traits affect the structure of a plant-frugivore network
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Talks and Symposia

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Colleen Downs	downs@ukzn.ac.za; University of KwaZulu-Natal	Molefe, K.L., Tedder, M.J., Thabethe, V., Rushworth, I.	University of KwaZulu-Natal	Role of native avian frugivores in germination facilitation and potential dispersal of invasive American bramble (<i>Rubus cuneifolius</i>) in South Africa
Caroline M. Dracxler	;	W. Daniel Kissling		Trait matching in Neotropical palm-frugivore interactions
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Yvette Ehlers Smith	yvetteehlers@hotmail.com; Centre of Functional Biodiversity, University of KwaZulu-Natal	Ehlers Smith, David	Centre of Functional Biodiversity, University of KwaZulu-Natal	Trees alone don't make a forest: assessing factors influencing forest regeneration within a fragmented habitat mosaic.
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Pierre-Michel Forget	pierre-michel.forget@mnhn.fr; Muséum National d'Histoire Naturelle, UMR MECADEV 7179 CNRS-MNHN	Aurélié Albert, Olivier Boissier, Opale Coutant, Axelle Bouiges, Caroline Dracxler, Marion Ducretet, François Feer, & Irène Mendoza	all co-authors with the same affiliation	Roads disrupt seed dispersal in animal-mediated plants in tropical forest
Evan Fricke	efricke@sesync.org; National Socio-Environmental Synthesis Center (SESYNC), University of Maryland	Svenning, Jens-Christian	Aarhus University	Introduced species in plant-frugivore networks: assessing impacts on network biogeography and predicting interactions under climate change
Pâmela Friedemann	pvfriedemann@gmail.com; Universidade de São Paulo	Côrtes, Marina & Guimarães Jr, Paulo Roberto	Universidade Estadual Paulista & Universidade de São Paulo	Palm tree-bird interaction network: do bird species and their roles change with Atlantic Forest types in southeast Brazil?
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Juan Pedro González-Varo	jpgvaro@outlook.com; Universidad de Oviedo (Spain)			Frugivorous birds operating as 'mobile links' in anthropogenic landscapes
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Julia Heinen	juliah@bio.ku.dk; Center for Macroecology, Evolution and Climate. University of Copenhagen	Michael Borregaard (and others)	Center for Macroecology, Evolution and Climate. University of Copenhagen. (and others)	New insights: Extinction-driven changes in frugivore communities on oceanic islands worldwide

Talks and Symposia

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Ruben Heleno	rheleno@uc.pt; Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Portugal	Coelho, Ana 2; Mendes, Filipa 1; Palmeirim, Jorge 2,3; Ramos, Jaime 4; Rainho, Ana 2,3; de Lima, Ricardo 2,3	1 Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Portugal; 2 Centre for Ecology, Evolution and Environmental Changes, Lisbon University, Portugal; 3 Departamento de Biologia Animal, Lisbon University, Portugal; 4 Marine and Environmental Sciences Centre, Department of Life Sciences, University of Coimbra, Portugal	The disruption of São Tomé seed-dispersal networks by alien vertebrates
Sandra Hervías-Parejo	shparejo@gmail.com; IMEDEA, UIB-CSIC	Tur, Cristina; Heleno, Ruben 2; M. Nogales 3, J. M. Olesen 4 & A. Traveset 1	1 Institut Mediterrani d'Estudis Avançats IMEDEA (CSIC-UIB), Mallorca, Balearic Islands, Spain 2 Centre for Functional Ecology, University of Coimbra, Portugal 3 Island Ecology and Evolution Research Group (CSIC-IPNA), Tenerife, Canaries, Spain 4 Department of Bioscience, Aarhus University, Denmark	Drivers of bird linkage level in coupled pollination and seed-dispersal networks
Jorge Isla	jorge.isla@ebd.csic.es; Integrative Ecology Group, Estación Biológica de Doñana, Sevilla (Spain)	Pedro Jordano, Miguel Jácome	Integrative Ecology Group, Estación Biológica de Doñana, Sevilla (Spain)/ Integrative Ecology Group, Estación Biológica de Doñana, Sevilla (Spain). + Centro de Cambio Global y Sustentabilidad, c/ Centenario del Instituto Juárez s/n, 86080 Villahermosa, Tabasco, Mexico.	Dispersal by animal frugivores and range expansion in plants: a multilayer network approach.
Landon Jones	jone1797@purdue.edu; Purdue University	Scott Duke-Sylvester, Paul Leberg, Derek Johnson	University of Louisiana at Lafayette, University of Louisiana at Lafayette, Virginia Commonwealth University	SEADS, a simulation modeling framework to compare spatial patterns of seed deposition by sympatric animal dispersers
Beth Kaplin	bkaplin@antioch.edu; Center of Excellence in Biodiversity & Natural Resources, Management, Rwanda; College of Science & Technology, University of Rwanda, Rwanda; University of Massachusetts-Boston, USA			Phenology and seed dispersal patterns in a tropical montane forest, Rwanda
Gitanjali Katlam	geetukatlam@gmail.com; Jawaharlal Nehru University	Prasad Soumya	Nature Science Initiative	Understanding foraging behaviour of frugivores species at garbage dumps
Shumpei Kitamura	shumpei@ishikawa-pu.ac.jp; Ishikawa Prefectural University, Japan	Terashima, Takuya	Ishikawa Prefectural University, Japan	Quantifying external seed dispersal by terrestrial mammals using camera trap data in a Japanese cedar plantation, central Japan
Anusha Krishnan	anusha.krishnan@gmail.com; Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India	Renee M. Borges	Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India	Constraints for population genetic variation via dispersal in a concrete jungle
Charles Kwit	ckwit@utk.edu; University of Tennessee	Patton, Maria; Miller, Chelsea; Lash, Chloe; Whitehead, Susan	University of New Mexico (Patton); University of Tennessee (Miller, Lash); Virginia Tech (Whitehead)	The role of seed disperser macro- and micro-biomes and chemicals on the seed dispersal loop
Inara Roberta Leal	irleal@ufpe.br; Universidade Federal de Pernambuco	Fernanda Maria Pereira O	Universidade Federal de Pernambuco	Myrmecochory in Brazilian Caatinga and its response to anthropogenic disturbance and climate change
Jun Ying Lim	junying.lim@ntu.edu.sg; (1) Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Amsterdam, The Netherlands (2) School of Biological Sciences, Nanyang Technological University, Singapore	Svenning, Jens-Christian (3), Gödel, Bastian (1,3), Faurby, Søren (4, 5), Kissling, W. Daniel (1)	(1) Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Amsterdam, The Netherlands (3) Department of Bioscience, Aarhus University, Denmark (4) Department of Biological and Environmental Sciences, University of Gothenburg, Sweden (5) Gothenburg Global Biodiversity Centre, Gothenburg, Sweden	Past and future extinctions shape the body size - fruit size relationship between palms and mammalian frugivores
Vivienne Loke Pei Wen		Lisa Ong, Kim McConkey, Param bin Pura, Husin a/l Sudin, Mohamad Tauhid bin Tunil (Cherang), Rizuan bin Angah, Loo Yenyi, Tan Wei Harn, Alicia Solana-Mena, Hii Ning and Ahimsa Campos-Arceiz.	Vivienne P.W. Loke ^{1,2} (first author for this abstract submission), Kim McConkey ¹ , Param bin Pura ² , Sudin A/L Din ² , Muhamad Tauhid bin Tunil (Charang) ^{1,2} , Rizuan bin Angah ^{1,2} , Loo Yenyi ³ , Tan Wei Harn ^{1,2} , Alicia Solana-Mena ^{1,2} , Hii Ning ² and Ahimsa Campos-Arceiz ^{1,2,4} . 1 School of Environmental and Geographical Sciences, The University of Nottingham Malaysia, Jalan Broga, 43500 Kajang, Malaysia 2 Management and Ecology of Malaysian Elephants, The University of Nottingham Malaysia, Jalan Broga, 43500 Kajang, Selangor, Malaysia 3 School of Biological Sciences, University of Auckland, Auckland, New Zealand 4 Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Mengla, Yunnan, 666303, China	Fruiting Phenology and Food Availability for the Belum Tropical Rainforest Community
Kim McConkey	kimmconkey@gmail.com; National Institute of Advanced Studies, Bangalore	(1) Carpenter, Jo; (1) Wilmshurst, Janet; (2) Hume, Julian; (3) Wotton, Debra; (4) Shiels, Aaron; (5) Drake, Don	(1) Manaaki Whenua – Landcare Research, NZ; (2) Natural History Museum, UK; (3) Moa's Ark Research, NZ; (4) National Wildlife Research Center, USA; (5) University of Hawaii, USA	The forgotten fauna: native seed predators on islands
Irene Mendoza	irene.mendoza@ebd.csic.es; Estación Biológica de Doñana (CSIC)	Pedro Jordano	Estación Biológica de Doñana (CSIC)	Temporal dynamics of seed-dispersal networks mediated by plant phenology in a Mediterranean scrubland
Erison C. S. Monteiro	oerison@yahoo.com.br; São Paulo State University (Unesp), Ecology Department, Institute of Biosciences, Rio Claro	Emer, Carine; Pizo, Marco A.	São Paulo State University (Unesp), Ecology Department, Institute of Biosciences, Rio Claro; São Paulo State University (Unesp), Zoology Department, Institute of Biosciences, Rio Claro	Evolutionarily distinct interactions, seed-dispersal networks and landscape fragmentation in a hotspot of biodiversity
Alessio Mortelliti	alessio.mortelliti@maine.edu; Department of Wildlife, Fisheries, and Conservation Biology University of Maine 5755 Nutting Hall, Orono, ME (USA) 04469	Brehm, Allison + Boone, Sara	Department of Wildlife, Fisheries, and Conservation Biology University of Maine 5755 Nutting Hall, Orono, ME (USA) 04469	Food for thought: effects of personality on seed dispersal in modified landscapes

Talks and Symposia

First Author	First Author email and affiliation	Co-authors	Co-author Affiliations	Presentation title
Juan Morales	jm.morales at conicet.gov.ar; CONICET and Universidad Nacional del Comahue, Argentina			Movement, frugivory and seed dispersal
Lindelwa Msweli	mswells30@gmail.com; DSI-NRF Centre of Excellence for Invasion Biology, and Centre for Functional Diversity, University of KwaZulu-Natal, Private Bag X01, Scottsville, 3209, South Africa	Christophe Baltzinger(2), Manqoba Zungu (1), Colleen T. Downs (1)	(1) DSI-NRF Centre of Excellence for Invasion Biology, and Centre for Functional Diversity, University of KwaZulu-Natal, Private Bag X01, Scottsville, 3209, South Africa. (2) Irstea, Research Unit Forest Ecosystems, Nogent-sur-Vernisson, France	Who is spreading the seeds? Fruit consumption of lantana (<i>Lantana camara</i>), bugweed (<i>Solanum mauritianum</i>), syringa (<i>Melia azedarach</i>) and cochineal prickly pear (<i>Opuntia monacantha</i>) by indigenous southern African ungulates
Miyabi Nakabayashi	miyabi.nakabayashi@gmail.com; Hiroshima University	Eyen Khoo	Sabah Forestry Department	Even small seeds need large seed dispersers
Rohit Naniwadekar	rohit@ncf-india.org; Nature Conservation Foundation			Understanding the role of large-bodied frugivores in seed dispersal
Shoji Naoe	naoeshoji@affrc.go.jp; Forestry and Forest Products Research Institute (FFPRI)			Phenology as a driver of local and long-distance seed dispersal by animals
Manuel Nogales	mnogales@ipna.csic.es; Island Ecology and Evolution Research Group (IPNA-CSIC), Canary Islands, Spain	Kim McConkey 2, Tomás A. Carlo 3, Debra Wotton 4, Peter Bellingham 5, Anna Traveset 6, Aaron González-Castro 1, Ruben Heleno 7, Kenta Watanabe 8, Haruko Ando 9, Don Drake 10	2 School of Natural Sciences and Engineering, National Institute of Advanced Studies, Bangalore, INDIA 3 Department of Biology, Penn State University, USA 4 Moa's Ark Research, Wellington, & Biological Sciences, University of Canterbury, Christchurch, NEW ZEALAND 5 Lancare Research, Lincoln, NEW ZEALAND 6 InstitutMediterranid'EstaudisAvançats (IMEDEA-CSIC), Balearic Islands, SPAIN 7 Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, PORTUGAL 8 Okinawa National Colleague of Technology, Okinawa Islands, JAPAN 9 Laboratory of Forest Biology, Kyoto University, JAPAN 10 Department of Botany, University of Hawaii, USA	A global review of frugivory and seed dispersal on islands
Lisa Ong	;	Kim McConkey, Param bin Pura, Husin a/I Sudin, Mohamad Tauhid bin Tunil (Cherang), Nurul Ain binti Amirrudin, Lily Ong and Ahimsa Campos-Arceiz		
Anand Osuri	aosuri@ncf-india.org; Nature Conservation Foundation	Mudappa, Divya, Shankar Raman, T. R.	Nature Conservation Foundation	Patterns of tree regeneration in degraded rainforest fragments suggest declines in seed dispersal and a role for ecological restoration
Liba Pejchar	liba.pejchar@colostate.edu; Colorado State University	Sandor, Manette Aslan, Clare Bronstein, Judie	American Museum of Natural History University of Northern Arizona University of Arizona	Predicting the effects of climate change on fruiting phenology
Mario Pesendorfer	mario.pesendorfer@yahoo.com; Institute of Forest Ecology, University of Natural Resources and Life Sciences, Vienna	Gratzer, Georg	Institute of Forest Ecology, University of Natural Resources and Life Sciences, Vienna	The effects of variation in seed crop size and phenology and dispersal kernels of seeds and seedlings in montane old-growth forests
Elena Quintero	equintero@ebd.csic.es; Integrative Ecology Group, Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain	Jordano, Pedro	Integrative Ecology Group, Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain	Super-generalist species in ecological networks: the role of biological traits in individual interactions
Geetha Ramaswami	geetha@ncf-india.org; Nature Conservation Foundation	Soumya Prasad, Monica Kaushik, Raman Sukumar, David Westcott, Suhel Quader	Nature Science Initiative; Wildlife Institute of India; Centre for Ecological sciences, CSIRO Australia, Nature Conservation Foundation	Dispersal by native frugivores affects management of an invasive plant species
Nancia Raelinjanakolona	nancia.raelinjanakolona@gmail.com; Université d'Antananarivo, BP 906, Madagascar, Domaine des Sciences et Technologies, Mention Zoologie et Biodiversité Animale	Onja Razafindratsima		Impact of habitat fragmentation on plant-frugivore mutualistic networks
Haldre Rogers	haldre@iastate.edu; Ecology, Evolution and Organismal Biology Department, Iowa State University in Ames, USA			Strategic rewilding to restore seed dispersal to a defaunated island
Tobias Nicolas Rojas	tobiasnrojas@gmail.com; Instituto de Ecología Regional (CONICET-UNT)	Ruggera, Román; Blendinger Pedro G.	Instituto de Ecoregiones Andinas (CONICET-UNJU); Instituto de Ecología Regional (CONICET-UNT)	Frugivores' morphological and chemical interaction niches relationship: It is not what it looks like
Erison Carlos dos Santos Monteiro	;	Carine Emer, Marco A. Pizo		Evolutionarily distinct interactions, seed-dispersal networks and landscape fragmentation in a hotspot of biodiversity
Spencer Schubert	scschubert11@gmail.com; Department of Biological Sciences, Old Dominion University	Walters, Eric	Department of Biological Sciences, Old Dominion University	Temporal dynamics of plant-frugivore networks in the tropical forests of Hispaniola

Talks and Symposia

First Author	First Author email and affiliation	Co-authors	Co-author Affiliations	Presentation title
Geno Schupp	eugene.schupp@usu.edu; Department of Wildland Resources & Ecology Center, Utah State University	Rafal Zwolak, Landon R. Jones, Rebecca S. Snell, Noelle G. Beckman, Clare Aslan, Brittany R. Cavazos, Edu Effiom, Evan C. Fricke, Flavia Montaña-Centellas, John Poulsen, Onja H. Razafindratsima, Manette E. Sandor, Katriona Shea		Review of individual trait variation in seed dispersal related traits
Elise Sivault	elise.sivault@edu.mnhn.fr; Mecadev UMR 7179 MNHN-CNRS, FUNEVOL team, 55 rue Buffon, 75005 Paris, France	Herrel, Anthony; Forget, Pierre-Michel; Fabre, Anne-Claire; Bretagnolle, François; McConkey, Kim; Heymann, Eckhard	Mecadev UMR 7179 MNHN-CNRS, FUNEVOL team, 55 rue Buffon, 75005 Paris, France ; Mecadev UMR 7179 MNHN-CNRS, ECOTROP team, 1 avenue du petit chateau, 91800 Brunoy, France ; Goswami lab, The Natural History Museum, Cromwell Road, London SW7 5BD ; University of Burgundy, Dijon, France ; Kuala Lumpur, University of Nottingham Malaysia Campus, Malaysia ; Deutsches Primatenzentrum, Göttingen, Germany	The body weight and skull measurements predict seed dispersal capacity in bat, primate and carnivore species.
Simon Stringer	simondstringer@googlemail.com; School of Biological and Environmental Sciences, Liverpool John Moores University, UK & Dept. of Zoology, University of Venda, South Africa	Hill, Russell A. Swanepoel, Lourens Dalrymple, Sarah Linden, Bibi Koyama, Nicola F.	Dept. of Anthropology, Durham University, UK & Primate and Predator Project, Lajuma Research Centre, South Africa Dept. of Zoology, University of Venda, South Africa & African Institute for Conservation Ecology, South Africa School of Biological and Environmental Sciences, Liverpool John Moores University, UK Lajuma Research Centre, South Africa & Dept. of Zoology, University of Venda, South Africa School of Biological and Environmental Sciences, Liverpool John Moores University, UK	Interpreting the role of frugivores in seed germination potential depends on study design: A case study from Soutpansberg Mountain, South Africa
Lauren Sullivan	;	Haldre Rogers		Natural seed dispersal can promote diversity in grassland restorations when safe sites are available.
Marcelo Taberelli	mtrelli@ufpe.br; Universidade Federal de Pernambuco	Inara Roberta Leal	Universidade Federal de Pernambuco	Leaf-cutting ants as a key sink for seeds and seedlings in neotropical human-modified landscapes
Vuyisile Tabethe	thabethevuyisile@yahoo.com; University of KwaZulu-Natal, South Africa	Amy-Leigh Wilson, Lorinda A. Hart, Colleen T. Downs		Ingestion by an invasive parakeet species reduces germination success of invasive alien plants relative to ingestion by indigenous turaco species in South Africa
John Terborgh	manu@duke.edu;			Seed dispersal and Janzen-Connell: how they interact.
Hugo Thierry	hugothieryp@gmail.com; Department of Ecology, Evolution and Organismal Biology, Iowa State University, USA	Rose Ethan , Rogers Haldre	Department of Ecology, Evolution and Organismal Biology, Iowa State University, USA	Strategic planning of rewinding of avian seed dispersers at different spatial scales
Jade Tonos	jadetonos@gmail.com; Department of Biosciences, Rice University	Onja Razafindratsima , Amy Dunham		Individual networks of plant-animal interactions: insights into spatial structure and influencing factors
Anna Traveset	atraveset@imedea.uib-csic.es; Global Change Research Group, Mediterranean Institute for Advanced Studies, CSIC- UIB Esporles, Mallorca, Spain	Gema ESCRIBANO-Avila, Juan Pedro González-Varo, and Jose Maria Fedriani		Mammal seed-dispersal mutualisms in changing Mediterranean ecosystems
Yamato Tsuji	ytsuji1002@gmail.com; Primate Research Institute, Kyoto University, Japan		Wildlife Management Office	Seed dispersal by Japanese macaques (<i>Macaca fuscata</i>) inhabiting rural areas in central Japan
Yamato Tsuji	ytsuji1002@gmail.com; Primate Research Institute, Kyoto University, Japan	Shintaro Ishizuka, Rismayanti, Takafumi Suzumura, Atsushi Takizawa, and Toshio Hagiwara	Bogor Agricultural University, Indonesia, Wildlife Research Center, Kyoto University, Japan, Jigokudani Monkey Park, Japan	Age difference in seed dispersal parameters found in Japanese macaques (<i>Macaca fuscata</i>)
Kim Valenta	kimvalenta@ufl.edu; Department of Anthropology, University of Florida	Omer Nevo	Institute of Evolutionary Ecology and Conservation Genomics University of Ulm	Animal-plant communication: the evolution of fruit signals
David L. Vergara-Tabares	davidlautarov@gmail.com; Instituto de Diversidad y Ecología Animal (UNC-CONICET) & Centro de Zoología Aplicada (FCEFYN-UNC), Córdoba, Argentina.	Pedro G. Blendinger, Agus	Instituto de Ecología Regional (UNT-CONICET), Tucumán, Argentina. Centro de Zoología	Seed dispersal of a native tree is promoted by the invasion of ornithocorous shrubs and modulated by their density
Nacho Villar	nachoprad@gmail.com; Instituto de Biociências, Departamento de Ecologia, Universidade Estadual Paulista (UNESP), CP 199, 13506-900 Rio Claro, São Paulo, Brazil	Paz, Claudia; Bulacoschi, Leticia; Akkawi, Paula; Siqueira, Tadeu; Zipparro, Valesca; Farah, Fabiano; Emer, Carine; Jordano, Pedro; Galetti, Mauro	Instituto de Biociências, Departamento de Ecologia, Universidade Estadual Paulista (UNESP), CP 199, 13506-900 Rio Claro, São Paulo, Brazil; Consejo Superior de Investigaciones Científicas, Estación Biológica de Doñana, Seville, Spain	The ecological consequences of defaunating complementary frugivore functions
Elisabet Wehncke	lizwehncke@gmail.com; Centro de Investigación en Biodiversidad y Conservación, Universidad Autónoma del Estado de Morelos, Mexico	Vanessa Montes de Oca	Facultad de Biología, Universidad Autónoma del Estado de Morelos, Mexico	Seed dispersal by fishes in rivers of Central Mexico tropical dry forests
Susan Whitehead	swhitehead@vt.edu; Department of Biological Sciences at Virginia Tech, USA			The diversity unseen: fruit phytochemical complexity and seed dispersal
Catherine Wynne	;	Lauren Sullivan		Quantifying seed rain patterns in a remnant and a chronosequence of restored tallgrass prairie

Speed talks and posters

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Balram Awasthi	awbalramsnsctu@gmail.com; EEPAL, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Yunnan, China Department of Zoology, Siddhanath Science Campus, Tribhuvan University, Nepal Email id: balram@xtbg.ac.cn; awbalramsnsctu@gmail.com			Current status of frugivory and seed dispersal research in Nepal
Puja Bishaya	pujabishaya@gmail.com; Wildlife Biology and Conservation Group Department of Environmental Biology and Wildlife Sciences Cotton University Panbazar, Guwahati - 781001, Assam	Narayan Sharma	Both: "Wildlife Biology and Conservation Group Department of Environmental Biology and Wildlife Sciences Cotton University Panbazar, Guwahati - 781001, Assam"	Effect of local disturbance on frugivorous birds in fragmented tropical rainforests.
Nasiphi Bitani	bitaninasiphi@gmail.com;	Colleen T. Downs	Centre for Excellence in Invasion Biology and Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa	Dispersal of invasive <i>Lantana camara</i> by native bird species in KwaZulu-Natal, South Africa
Tamara Burgos	tamaraburgos44@gmail.com; Department of Biology, Geology, Physics and Inorganic Chemistry, King Juan Carlos University, C/ Tulipán s/n, 28933, Móstoles, Madrid, Spain	Emilio Virgós, Javier Seoane, José María Fedriani, Gema Escribano-Ávila, Inmaculada Cancio and Javier Rodríguez-Siles	Emilio Virgós: Department of Biology, Geology, Physics and Inorganic Chemistry, King Juan Carlos University, C/ Tulipán s/n, 28933, Móstoles, Madrid, Spain. Javier Seoane: Department of Ecology, University Autonomous of Madrid, c/ Francisco Tomás y Valiente, 7, 28049, Madrid, Spain. José María Fedriani: Department of Conservation Biology, Doñana Biological Station (EBD-CSIC), Seville, Spain Gema Escribano-Ávila: Department of Biology, Geology, Physics and Inorganic Chemistry, King Juan Carlos University, C/ Tulipán s/n, 28933, Móstoles, Madrid, Spain. Inmaculada Cancio: Department of Biology, Geology, Physics and Inorganic Chemistry, King Juan Carlos University, C/ Tulipán s/n, 28933, Móstoles, Madrid, Spain. Javier Rodríguez-Siles: Asociación de Estudio y Conservación de Fauna Harmusch, C/San Antón 15, 13580, Almodóvar del Campo, Ciudad Real, Spain	The Iberian lynx (<i>Lynx pardinus</i>) as a modeler of seed dispersal through trophic cascades
José L. Tella >> Martina Carrete	tella@ebd.csic.es;	Fernando Hiraldo, Erica Pacifico, José A. Díaz-Luque, Francisco V. Dienes, Fernanda M. Fontoura, Neiva Guedes, Guillermo Blanco		Threatened hyacinth and Lear's macaws are legitimate seed dispersers of plants with megafaunal fruits.
Cristiane Tibério Checon	cricachecon@gmail.com;	Mariana Franciscão Costa, Wesley Rodrigues Silva	Universidade Estadual de Campinas (UNICAMP) Instituto de Biologia Departamento de Biologia Animal Rua Monteiro Lobato, 255 CEP 13.083-862 - Campinas - SP - Brasil	The Picazuro pigeon: seed predator or unexpected disperser?
José Otavio Venancio Ferreira	z.venanciof@gmail.com;	Wesley Rodrigues Silva; Jasmim Oliveira	Universidade Estadual de Campinas (UNICAMP) Rua Monteiro Lobato, 255 CEP 13.083-862 - Campinas - SP - Brasil	Induced seed dispersal by frugivorous vertebrates at a restored forest in southeastern Brazil
Holly M. Garrod	hmg20@humboldt.edu;	Spencer C. Schubert		Unexpected frugivory in a Caribbean-endemic bird
Abhishek Gopal	abhishekgopal1993@gmail.com; National Centre for Biological Sciences, Bangalore	Dr. Rohit Naniwadekar, Dr. Divya Mudappa	Both: Nature Conservator Foundation, Bangalore	Differential impacts of forest cover loss on frugivory and seed predation of four rainforest tree species in the southern Western Ghats, India
Dailos Hernández-Brito	dailoshb@ebd.csic.es; Department of Conservation Biology, Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (CSIC), Avda. Américo Vespucio, 41092, Sevilla, Spain	Guillermo Blanco, Martina Carrete & José L. Tella	Dailos Hernández-Brito and JL Tella: Department of Conservation Biology, Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (CSIC), Avda. Américo Vespucio, 41092, Sevilla, Spain Guillermo Blanco: Department of Evolutionary Ecology, Museo Nacional de Ciencias Naturales, Consejo Superior de Investigaciones Científicas (CSIC), José Gutiérrez Abascal 2, 28006, Madrid, Spain Martina Carrete: Department of Physical, Chemical and Natural Systems, University Pablo de Olavide, Ctra. de Utrera, km. 1, 41013, Sevilla, Spain	The role of parrots as seed dispersers in the scenario of biological invasions
Abir Jain	abir.blb@gmail.com; Wildlife Science, Wildlife Institute of India, Dehradun	Dr. Rohit Naniwadekar, Dr. Navendu Page, Dr. G.S. Rawat	Dr. Navendu Page Scientist, Wildlife Institute of India Dr. G S Rawat Scientist, Wildlife Institute of India Dr. Rohit Naniwadekar Scientist, Nature Conservation Foundation	Plant-seed disperser interactions in fragmented lowland tropical forests of north-east India
Puttaraju. K	blueglasstiger@gmail.com; NPCIL, Kaiga Generating Station, Kaiga – 581 400, Uttara Kannada, Karnataka, Mob:+91 9448999150	Bhanusri S. P	Department of Life Science, Bangalore University, Jnanabharathi campus, Bengaluru-560056	Feeding habits of the great hornbill (<i>Buceros bicornis</i>) in Kaiga, Uttarakannada, Southern Wesytern Ghats, India
Sara Beatriz Marques Mendes	sarabmmendes@gmail.com; Department of Life Sciences, Centre for Functional Ecology (CFE-UC), University of Coimbra, Coimbra, Portugal	Catherine J. O'Connor, Jens M. Olesen, Ruben H. Heleno	Cardiff School of Biosciences, Cardiff University, Cardiff, UK; Department of Bioscience, Aarhus University, Aarhus, 8000, Denmark; Department of Life Sciences, Centre for Functional Ecology (CFE-UC), University of Coimbra, Coimbra, Portugal	Is there a seed dispersal crisis in Europe?
Laura Obando-Cabrera	lobandoc@unal.edu.co;	Oscar Murillo		Effect of disturbance on mutualistic networks of fruit bats in a tropical rainforest
Natalia Paes	natalia.dpaes@gmail.com;	Wesley Silva; Fernanda Ribeiro da Silva, Paulo Antônio de Almeida Sinisgalli	Universidade Estadual de Campinas (UNICAMP) Instituto de Biologia Rua Monteiro Lobato, 255 CEP 13.083-862 - Campinas - SP - Brasil	How much the birds contribute for restoration areas?
Islamiat Abidemi Raji	abiraj4success@gmail.com;	Vuyisile Thabethe, and Colleen T. Downs		The role of avian frugivores in the germination of keystone <i>Ficus</i> species in KwaZulu-Natal, South Africa

Speed talks and posters

First Author	First Author email and affiliation	Co-authors	Co-author Affiliations	Presentation title
Veronarindra Ramananjato		Zafimahery Rakotomalala (University of Antananarivo), Camille DeSisto (Harvard University), Daniel S. Park (Harvard University), Nancia N. Raoelijnanakolona (University of Antananarivo), Nicola Guthrie (University of Calgary), Zo E. S. Fenosoa (University of Antananarivo), Steig E. Johnson (University of Calgary) and Onja H. Razafindratsima (South Dakota State University)	Zafimahery Rakotomalala (University of Antananarivo, Madagascar), Camille DeSisto (Harvard University, USA), Daniel S. Park (Harvard University, USA), Nancia N. Raoelijnanakolona (University of Antananarivo, Madagascar), Nicola Guthrie (University of Calgary, Canada), Zo E. S. Fenosoa (University of Antananarivo, Madagascar), Steig E. Johnson (University of Calgary, Canada) and Onja H. Razafindratsima (South Dakota State University, USA)	Smallest nocturnal primates facilitate seed germination and seedling growth in rainforests
Eduardo Delgado Brites Rigacci	eduardorigacci@gmail.com;	Wesley Rodrigues Silva	Universidade Estadual de Campinas (UNICAMP) Rua Monteiro Lobato, 255 CEP 13.083-862 - Campinas - SP - Brasil	The resilient frugivorous fauna of a degraded forest fragment and its potential role in the enrichment of vegetation
Spencer C. Schubert	scschubert11@gmail.com; Department of Biological Sciences Old Dominion University Norfolk, VA 23529-0266	Eric L. Walters	Both: Department of Biological Sciences Old Dominion University Norfolk, VA 23529-0266	Artificial perches as a technique for enhancing tropical forest restoration
Tinyiko Cavin Shivambu	shivambucavin@gmail.com; Centre for Excellence in Invasion Biology and Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg, 3209, South Africa.	Ndivhuwo Shivambu, and Colleen T. Downs	same as main author	Feeding biology of invasive rose-ringed parakeets <i>Psittacula krameri</i> in urban landscapes of eThekweni Metropole, KwaZulu-Natal Province, South Africa
Manpreet Singh				Role of small mammals in seed dispersal, predation and germination : A review
P S Sumashini	sumashini.sundararajan@gmail.com;	Qamar Qureshi, Manoj Nair, Amit Kumar		Impact of habitat fragmentation on diurnal squirrels in the lowland tropical forests of upper Assam, north-east India
Kaori Takahashi		Taiga Amari, Moe Ide, Kosuke Saeki, Yutaro Koide, Kengo Kawamoto, Kazuaki Takahashi	Affiliation of them is Faculty of Tourism and Environmental Studies, Nagano University.	Morphological and nutritional characteristics of Japanese crowberry's berries that are used by Japanese black bears.
Kazuaki Takahashi		Shoji Naoe, Kosuke Saeki, Yutaro Koide, Taiga Amari, Yoshihiro Tsunamoto, Ichiro Tayasu, Takashi F. Haraguchi, Kaori Takahashi		Vertical seed dispersal of Japanese crowberry by Japanese black bears and birds: estimation using stable oxygen isotope ratios.
Yamato Tsuji	ytsuji1002@gmail.com;	Hironori Seino, Hiroshi Ebihara	Yamato Tsuji ¹ , Hironori Seino ² , and Hiroshi Ebihara ² ¹ Primate Research Institute, Kyoto University, Japan ² Wildlife Management Office, Japan	Seed dispersal by Japanese macaques (<i>Macaca fuscata</i>) inhabiting rural areas in central Japan
Giovanni Villa			USM, University Sains Malaysia - 11800 Gelugor, Penang, Malaysia; MNeP: Macaca Nestrina Project	Exploring the role of <i>Macaca nemestrina</i> as seed disperser
Suann Yang	yang@geneseo.edu; Biology Department State University of New York at Geneseo Geneseo, NY, US	Evan Burr, Lauren Ellis	All: *Biology Department State University of New York at Geneseo Geneseo, NY, US*	Pre-dispersal frugivory and seed predation by insects in an invaded plant community
Manqoba M. Zungu				Digestive efficiencies of frugivorous birds fed varying concentrations of equicaloric glucose and sucrose artificial fruit diets