LIFE AT THE EDGE

EARLY CAREER INVESTIGATOR PROGRAM

INTERNATIONAL ASSOCIATION FOR PLANT TAXONOMY

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Botany 2019 Conference, 28-31 July 2019 | Tucson, AZ

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21-28 July 2019 | Tucson AZ - USA

A note from the president

The International Association for Plant Taxonomy supports scientific research and scholarship in the field of systematics, including taxonomy and evolution, of plants, fungi, and algae. IAPT has established a symposium series called the Early Career Investigator Symposium to highlight the research of botanists, mycologists, and phycologists. Each year the symposium will be presented at a different international conference where IAPT participates in the program. The specific theme will vary from year to year, depending on the theme of the conference. This year the theme for our symposium at the Botany 2019 conference is "Life at the Edge," which I think fits quite well with the conference theme "Sky Islands & Desert Seas."

Patrick Herendeen
President of IAPT

Cover photo
Chile's Atacama desert is a land of extremes. Ranking as the driest place on Earth, this unique desert is home to many endemics which cling for survival in places such as this salt lake that sits above 4000 m asl.
Photo: M. Bonifacino, 2014

A note from the organizers

The International Association for Plant Taxonomy (IAPT) supports scientific research in systematics of plants, fungi, and algae. This is the third event of a series sponsored by the IAPT to highlight the work of young researchers.

Taxa occupying evolutionarily novel habitats, whether these fit into our conventional concepts of extreme environments (e.g. deserts, mountaintops, polar regions) or are "extreme" only relative to the ancestral habitats of the lineage (e.g. forest canopy, temperate climates, land), must evolve new solutions to the challenges of survival and reproduction. Understanding how these taxa adapted to their novel niches and the impacts of this habitat shift on species biology and the process of speciation offers a fascinating window on evolution: insight both into events of the past, and events we might anticipate as human-caused global change places more and more species into evolutionarily novel environments.

This program will highlight research conducted in the fields of systematics and evolution of major clades of fungi and plants, focusing on how life has pushed the edge of what constitutes a habitable environment.

We thank the Botany 2019 meeting for providing the venue and IAPT for the invitation to organize the program and for providing the funding for the registration and travel support for the speakers.

Many thanks for joining us! Enjoy!

Tatyana Livshultz

Mauricio Bonifacino

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INTO THE TREES AND BACK AGAIN: MAJOR ECOLOGICAL SHIFTS DRIVE THE RADIATION OF NEOTROPICAL *PHLEGMARIURUS*

Weston Testo

Into the trees and back again: major ecological shifts drive the radiation of Neotropical *Phlegmariurus*

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Key words: Andes, diversification, lycophyte, paramo, sky islands, systematics.

The clubmoss family Lycopodiaceae is an ancient family of vascular land plants with a cosmopolitan distribution and an estimated 400 species globally. Nearly three-quarters of the family's species richness is comprised of members of the pantropical genus *Phlegmariurus*, which includes lineages that have adapted to a remarkable diversity of habitat types and ecological niches. The genus is especially diverse and taxonomically complicated in the American tropics, where species occur in humid habitats from 0 to 5000 meters elevation. By generating a densely sampled and robustly supported phylogeny, we infer the timing and tempo of the clade's diversification and use an array of macroevolutionary models to identify drivers of its exceptional evolutionary success. We demonstrate that the diversification of Neotropical *Phlegmariurus* is closely linked to the uplift of the northern Andes mountains, which provided opportunity for colonization of novel and highly fragmented "sky island" habitats that correspond to the modern paramo ecosystem. This work is the first to explicitly examine drivers of diversification in a group of Andean spore-dispersed plants and complements similar studies in angiosperms.

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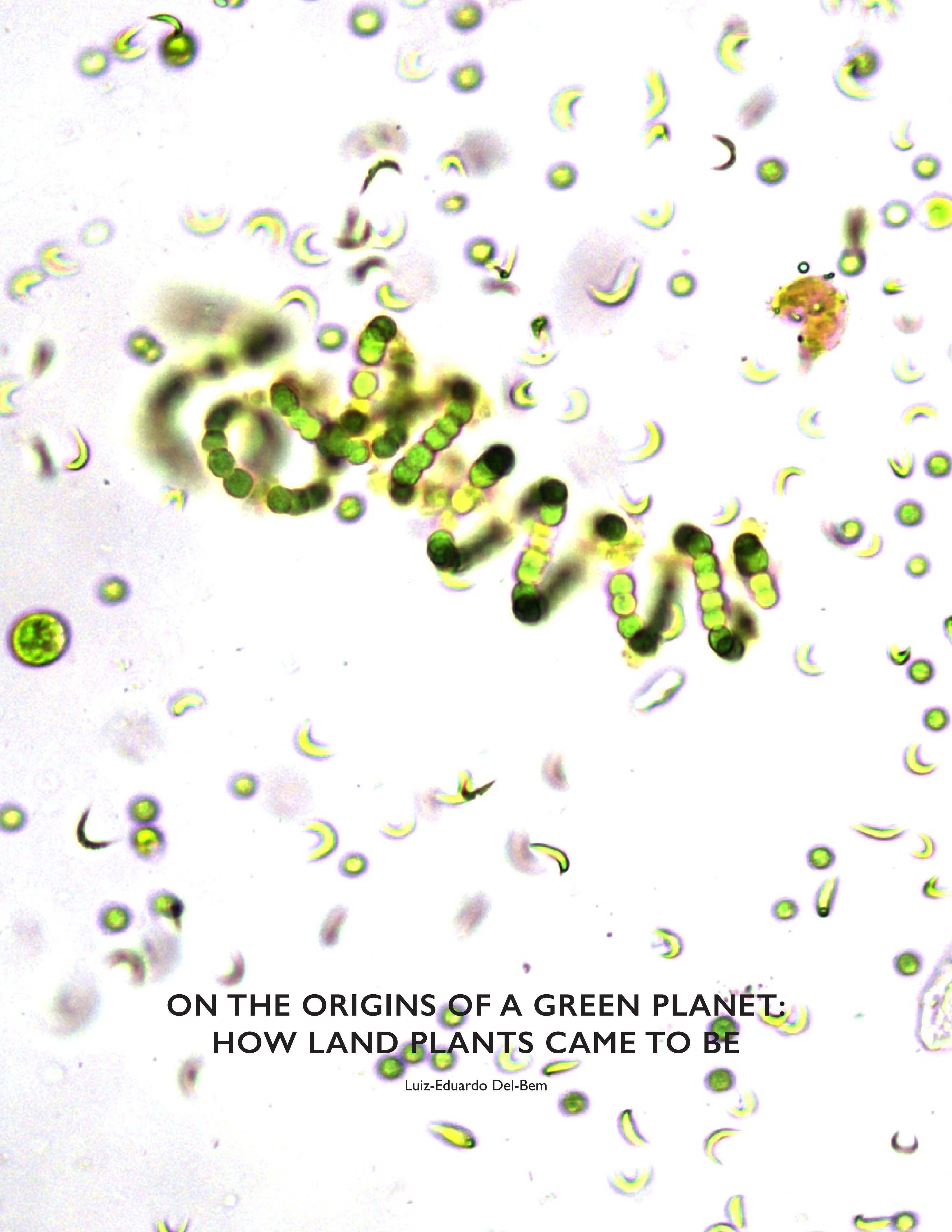
I am interested in understanding how various factors - hybridization, migration, climate change, polyploidy, to name a few - have driven the evolution of ferns and lycophytes, especially in the American tropics. My research integrates disparate but complementary approaches such as biogeography, herbarium study, field work, and phylogenomics both to resolve species complexes in taxonomically challenging groups and to improve our understanding of large-scale features of the land plant tree of life. For my PhD studies at the University of Vermont, I examined the evolution of the lycophyte family Lycopodiaceae, with a focus on untangling the evolutionary history of the New World species in the genus *Phlegmariurus*. I am currently completing a postdoc at the University of Florida, where I am working on the Genealogy of Flagellate Plants (GoFlag) project, which seeks to contribute to improve our understanding of land plant evolution by generating and analyzing sequence data from hundreds of loci for more than 8,000 species of bryophytes, lycophytes, ferns and gymnosperms.

Article title's photo
An undescribed species of Phlegmariurus *endemic to the Cordillera Oriental of the Colombian Andes.*
Photo: W. Testo, 2018



ON THE ORIGINS OF A GREEN PLANET: HOW LAND PLANTS CAME TO BE

Luiz-Eduardo Del-Bem

On the origins of a green planet: how land plants came to be

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Key words: Plant Evolution, Charophyta, Embryophyta, Xyloglucan, Biological Soil Crusts.

The colonization of land environments by living matter is one of the key evolutionary events in the history of life on Earth. The most complex life forms we know evolved on land: mammals, birds, and flowering plants. Terrestrial life has also developed into some of the most diverse and ecologically complex communities: the rainforest ecosystems. Besides the immense scientific importance of addressing the question of how life colonized land masses, little is known about how and when this process happened. Some questions that remain to be answered are the nature of the first terrestrial ecological communities, the origins of biologically active soils, and the origin of land plants that ultimately gave rise to ancestral and extant forests. Most biologists tend to believe that the terrestrialization of plants started with early embryophytes that emerged from a group of multicellular aquatic charophycean green algae, evolving in the margins of drying pools. However, Stebbins and Hill proposed a very different hypothesis in 1980, that embryophytes emerged from unicellular charophycean green algae that colonized land environments long before the origin of embryophytes themselves. This view has been further supported by recent studies of plant cell wall evolution. Among the evidence from cell wall studies, the presence of the complete gene repertoire for xyloglucan synthesis and degradation in early-branching terrestrial charophytes from the class Klebsormidiophyceae stands out. Xyloglucan is a polysaccharide that was recently demonstrated to be released by roots and rhizoids of all groups of land plants as a sticky molecule able to modify soil properties. Xyloglucan likely evolved during the process of land colonization by early charophytes and could represent a key adaptation of photosynthetic biological soil crusts that could impact the early process of soil formation. This talk will present evidence for a new theory regarding the origin of land plants from a group of simple terrestrial charophycean green algae that was part of complex terrestrial ecosystems of microorganisms that relied on photosynthesis as carbon source, hundreds of millions of years before the first embryophytes. Emphasis will be put on the possible role of these early terrestrial communities of microorganisms as a main source of the genetic adaptations that allowed the efficient colonization of land environments by the plant lineage and eventually led to the evolution of embryophytes from terrestrial charophytes.

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I am an Adjunct Professor of Evolutionary Genomics at the Department of Botany of the Federal University of Minas Gerais (UFMG) in Belo Horizonte-MG, Brazil and obtained my B.Sc. in Biology, M.Sc. and Ph.D. in Genetics and Molecular Biology at University of Campinas (UNICAMP – Campinas-SP, Brazil). Later on I did a postdoctoral fellowship at Harvard University (HSPH – Boston-MA, US). My research line integrates comparative genomics and functional genetics to understand the molecular basis of the great transitions in plant evolution, focusing on the origin of land plants and the evolution of plant cell wall.

Article title's photo

Complex assemblages of green algae and Cyanobacteria possibly represent the earliest photosynthetic terrestrial communities. The first embryophytic common ancestor evolved from a group of charophycean green algae that most likely was part of such terrestrial ecosystems.
Photo: L.E Del-Bem, 2018

FROM SALT MARSHES TO SKY ISLANDS, PHYLOGENETICS OF NORTH AMERICAN *GRINDELIA* (ASTERACEAE)

Abigail Moore, Leann Monaghan & Adjoa Ahedor

From salt marshes to sky islands, phylogenetics of North American *Grindelia* (Asteraceae)

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Key words: Compositae, ecological adaptation

Grindelia (Asteraceae) occurs in dry, open habitats throughout the Americas. The genus as a whole has an amphitropical disjunction between reciprocally monophyletic North American and South American clades. The North American clade contains approximately 40 species, which are found throughout the western two-thirds of the continent, in grasslands, shrublands, and areas with saline or serpentine soils. The Rocky Mountains appear to have been a substantial geographic barrier for North American *Grindelia*, with distinct clades distributed west and east of the mountains. However, a few species occur in openings in mountain forests throughout the southern part of the Rockies and ranges to the south and west. Convergent ecological adaptation to montane habitats, as well as saline soils and areas with varying degrees of drought, has occurred in each of the major clades, sometimes multiple times.

We are using transcriptome sequencing to understand ecological evolution in North American *Grindelia* and to determine when and how often the different habitats were colonized. In addition, we are looking at whether hybridization with plants that were already adapted to those habitats helped other species colonize them later, and on the influence of polyploidization on ecological diversification.

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I am an assistant professor and curator of the Bebb Herbarium at the University of Oklahoma. My lab is studying ecological adaptation and phylogeography, with an emphasis on groups that occur in the southern Great Plains and southwestern deserts of North America. I am especially interested in the diverse family Asteraceae, and the influence of hybridization and polyploidy on diversification. I got my B.S. at the University of Utah, working with Dr. Lynn Bohs on the phylogeny of *Balsamorhiza* and *Wyethia*, and my Ph.D. at the University of California, Berkeley, working with Dr. Bruce Baldwin on phylogenetics and evolution of *Grindelia*, especially the California species. My first postdoc was at Johannes Gutenberg-Universität Mainz with Dr. Joachim Kadereit to look at adaptation of *Cherleria* to different soil types in the European mountains. I did a second postdoc at Brown University with Dr. Erika Edwards to look at evolution of CAM photosynthesis and drought adaptation in the Anacampserotaceae and other relatives of cacti.

Article title's photo
Grindelia ciliata *(Asteraceae) pollinated by an* Agapostemon *(Halictidae) bee on the edge of a ranch field in Gray County, Texas. Due to their reliable late-summer flowering, ability to grow in disturbed habitats, and abundant pollen,* Grindelia *are important food sources for bees and other insects. Photo: A. Moore, 2018*

DO EXTREME ENVIRONMENTS SELECT FOR REPRODUCTIVE ASSURANCE?

Kathryn Theiss

Do extreme environments select for reproductive assurance?

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Key words: *Oenothera*, Breeding System, desert

Predicting how plant species will evolve in the face of global climate change is one of the most important and challenging fields in current botanical research. Climate change affects the timing of plant flowering as well as activity of pollinators, which could lead to increased rates of self-fertilization, decreasing genetic diversity and therefore adaptive potential. Understanding the outcomes of a potential shift in the balance between self-fertilization (or selfing) and outcrossing will be extremely important as we predict how plants will maintain genetic diversity in the face of changes in reproductive strategy.
Plant breeding systems are influenced by competing evolutionary forces at both population and species levels. Multiple biological factors such as life history and pollination syndrome as well as abiotic parameters including ecological conditions and geography play a part in determining levels of inbreeding depression and reproductive assurance. Taxonomic groups that show high levels of variation in these parameters are useful in teasing apart these evolutionary forces, and the evening primroses, *Oenothera* (Onagraceae) are one of these groups. Previous research demonstrated that self-compatibility was associated with extreme environments, with taxa growing in colder or drier areas having the highest levels of self-compatibility. Recently my students and I have explored this pattern further in the pale evening primrose, *Oenothera pallida* ssp. *pallida*. Collecting material from across the entire geographic range of this taxon, we examined the population genetic patterns in *Oenothera pallida* ssp. *pallida* using microsatellite markers. We found varying levels of inbreeding that did not always align with the breeding system patterns. I will discuss possible future challenges for this taxon, and other desert taxa, as environmental changes continue to occur.

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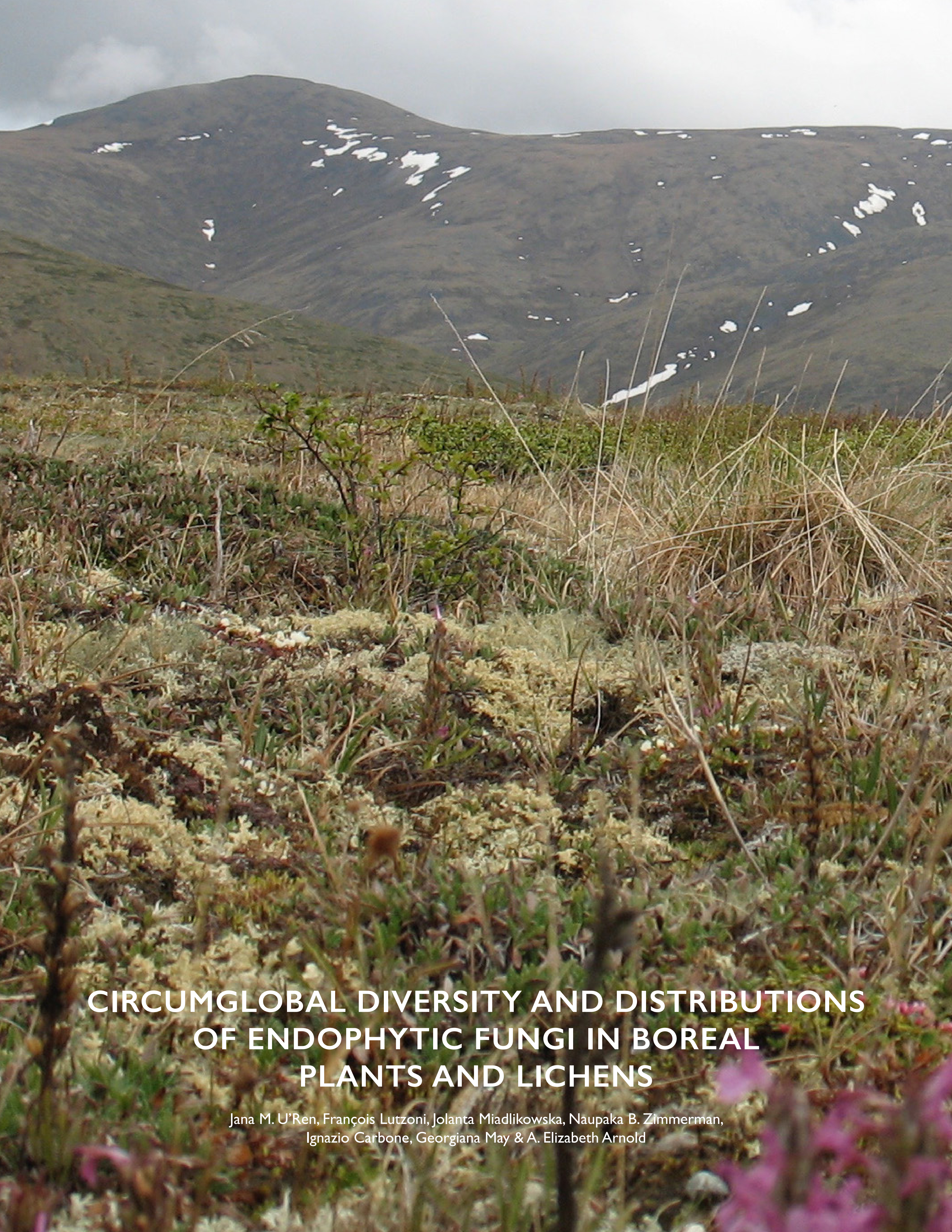
I am an Assistant Professor at California State University, Dominguez Hills in the Biology Department. I obtained my B.A. at Willamette University and my Ph.D. at the University of Connecticut. I then returned to Willamette University for a postdoctoral position before moving to Los Angeles. I have always been interested in plant-pollinator relationships, especially in systems with complicated flowers or limited pollinators, and have worked with milkweeds (*Asclepias*), orchids (*Erasanthe*), and evening primroses (*Oenothera*) among others. Currently I split my time between urban milkweed ecology and desert floral research. I am most thankful for my student collaborators who keep me inspired on a daily basis.

Article title's photo
Oenothera pallida *ssp.* pallida *at St. Anthony's Dunes, Idaho. Photo: Theresa Barosh, 2019.*



CIRCUMGLOBAL DIVERSITY AND DISTRIBUTIONS OF ENDOPHYTIC FUNGI IN BOREAL PLANTS AND LICHENS

Jana M. U'Ren, François Lutzoni, Jolanta Miadlikowska, Naupaka B. Zimmerman,
Ignazio Carbone, Georgiana May & A. Elizabeth Arnold

Circumglobal diversity and distributions of endophytic fungi in boreal plants and lichens

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Key words: Ascomycota; fungal diversity; endolichenic fungi; endophytes; plant–fungal symbioses

Plant-associated fungal communities are increasingly recognized for their potential to facilitate rapid adaptation of plants to novel stressors, especially within extreme environments. Long under-studied because of their cryptic occurrence in healthy above-ground tissues, fungal endophytes that occur within photosynthetic tissues of plants and in association with photosynthetic partners in lichens are emerging as key players in host health, productivity, and stress mitigation. Endophytes represent the most highly diverse fungal symbionts of photosynthetic hosts and comparative studies reveal that they reach their greatest phylogenetic diversity in high latitude ecosystems such as boreal forests, exceeding that even of tropical regions (where species richness is higher, but phylogenetic diversity is lower). Using replicated sampling of the same host species and/or genera in seven sites across the boreal biome of North America and Eurasia (20 plant and lichen species per site) in conjunction with culture-based and culture-free next-generation (NGS) amplicon sequencing, we examined whether the diversity and distributions of endophyte communities in the boreal realm reflect deterministic processes such as host- and environmental filtering or neutral processes such as dispersal and drift. Overall, we recovered >6,000 putative endophyte species using culture-free NGS paired with Sanger sequencing of >11,000 cultures. Endophyte richness based on culturing and NGS were positively correlated, and both methods recovered the same classes and families of Ascomycota. Repeated sampling of a focal site in Alaska illustrates the previously unexplored temporal stability of boreal endophyte communities, with a particularly high stability in long-lived lichen thalli. In describing global-scale patterns of endophyte host associations across phylogenetically diverse plants and lichens, this work represents a critical baseline to understand how local and regional extirpation of plants and lichens due to climate change will impact endophyte diversity and functions in the boreal biome.

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I am an Assistant Professor at the University of Arizona, Department of Biosystems Engineering and BIO5 Research Institute. I obtained my B.A. in Biological Sciences at the University of Missouri-Columbia and Ph.D. in Plant Pathology at the University of Arizona. I was the lead postdoctoral researcher on an NSF Dimensions of Endophyte Biodiversity grant, where I addressed patterns of endophyte diversity and host associations in phylogenetically diverse boreal plants and lichens at spatial scales ranging from local to global. I completed a second postdoctoral research position in computational metagenomics also at the University of Arizona before starting my faculty position as part of the Ecosystem Genomics Initiative at UA. Pairing large-scale culturing efforts with culture-free next generation amplicon sequencing and genomics, my research integrates ecological, phylogenetic, and functional data to test hypotheses regarding the evolution of fungal-photobiont interactions and their importance for ecosystem processes such as nutrient cycling.

Article title's photo

In Eagle Summit, Alaska (pictured here) the photosynthetic tissues of boreal plants and lichens are host to highly diverse assemblages of endophytic fungi. Comparative studies reveal that fungal endophytes reach their greatest phylogenetic diversity in high latitude ecosystems such as boreal forests, exceeding that even of tropical regions.
Photo: A. Elizabeth Arnold, 2011.

THERMAL TOLERANCES OF PLANTS: GEOGRAPHICAL PATTERNS AT GLOBAL AND LOCAL SCALES

Aelys M. Humphreys, Jan-Niklas Nuppenau, Nikolaos Minadakis & Lesley T. Lancaster

Thermal tolerances of plants: geographical patterns at global and local scales

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Key words: geothermal heating, grasses, land plants, latitude, Poaceae, temperature

Temperature is considered one of the strongest determinants of plant distribution patterns globally. Yet, our understanding of what drives the geographic distribution of plant thermal tolerances is poor. In this context, I will present preliminary results of two ongoing projects. In the first, we are analysing the global distribution of plant thermal tolerances. Previous studies of ectothermic animals suggest that thermal tolerance breadth increases toward the poles. Explanations for this pattern include local adaptation to the more variable conditions at high latitudes, phylogenetic (physiological) constraints limiting variation in upper thermal limits and biogeographic history related to species' recent range expansions. Using a newly compiled global dataset of measured upper and lower critical thermal limits (cold and heat tolerance) for land plants, we show that plants exhibit the expected latitudinal patterns but that there is no single explanation for these patterns. Instead we suggest that global variation in thermal tolerances is generated by several processes acting at different temporal and geographical scales. In the second project, we are studying grasses (Poaceae) from geothermally heated and non-heated areas of Iceland. Geothermally heated soils in Iceland never freeze and are on average 10 °C warmer than surrounding soils throughout the year. Fine temperature gradients over short geographic distances have made this an attractive system for studying the effect of warming on plant phenology. However, the winter season has received less attention and we do not know whether there is a tradeoff between adapting to warm soils and the ability to survive a normal temperate winter. Using common (winter) garden experimentation, we are comparing the winter survival ability and phenology of populations from heated and non-heated soils. We are also studying the population structure and phylogeography to assess the nature of any ongoing gene flow among populations. A previous study of *Agrostis* in North America found restricted gene flow among populations on heated and non-heated soils because of a shift to earlier flowering on the heated soils. At the time of writing we are only just beginning to see results for Iceland and I will summarise these in my talk.

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I am Assistant Professor of Plant Systematics at Stockholm University. I obtained a BSc in Biology (Plant Science Honours) at the University of Edinburgh, followed by an MRes in Biosystematics at Imperial College London and the Natural History Museum London. I obtained my PhD from the University of Zurich under the supervision of Peter Linder, where my thesis focused on generic delimitation and evolution of a clade of Southern Hemisphere grasses (Danthonioideae, Poaceae). I split my postdoc years between Imperial College and Stockholm University, working together with Timothy Barraclough and Catarina Rydin on a novel approach for studying how biodiversity is patterned and evolves above the level of species. My work combines comparative, genetic and experimental approaches but is primarily at the interface between macroevolution and macroecology. Current research questions include how plants adapt to temperate climates and the role of cold tolerance and life history traits in generating global distribution patterns of plants.

Article title's photo
Agrostis stolonifera *growing on a warm bed of thyme and bryophytes at a geothermally heated site in Iceland. These plants can obviously tolerate heat, but are they still able to tolerate a northern temperate (non-heated) winter? Photo: Jan-Niklas Nuppenau, 2018*