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SPECIAL TOPIC - PREFACE

Preface: Honoring the career of Professor James R. Ehleringer

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Early spring is a special time in the desert southwest of North America. This is the time of an annual scientific pilgrimage, about to enter its fourth decade. On the opening eve of each year's visit, a group of students, postdocs, volunteers and professors can be found huddling around a campfire in Death Valley National Park, pushing away the evening chill and making plans for what they will do the next day. It is time for the annual "hunt" for the pubescent shrub, *Encelia farinosa*. Enjoying the company of fellow botanists that Professor Jim Ehleringer has assembled, everyone has come to experience for oneself the passion and curiosity that have driven Jim and his students to repeatedly visit these yellow-capped, drought-deciduous plants that hold their ground on one of the harshest landscapes on earth. Armed with maps, meter sticks, and sampling tools of any-and-all sorts, the caravan of dedicated ecologists, nature enthusiasts, and lovers of "all-things desert" head off to count and quantify who is and is not present within several targeted populations. Jim initiated the pilgrimage during the days of his dissertation research with Hal Mooney and Olle Björkman at Stanford University. The opening paper in this Special Issue of *Oecologia* by Jim and his former student and long-time collaborator Darren Sandquist tells the story of what they have discovered and learned about *E. farinosa* in an unprecedented multi-decadal demographic analysis. The paper is the first of 16 papers dedicated to Jim's distinguished career and its impact on plant and ecosystem ecology writ large, including stable isotope ecology, desert ecology, photosynthetic adaptation, global change biology, urban ecology, paleobiology, forensic science, and atmosphere–biosphere interactions. This special issue of *Oecologia* is a fitting venue within which to honor Jim, not only because of his impressive set of scientific accomplishments, but also because he served as Editor-in-Chief of this journal for 16 years, steering much of its recognition and development in the disciplines of plant ecology. Furthermore, Jim has mentored many students, and postdoctoral fellows who are now productive scientists, policy makers, and teachers. This special issue allows us the opportunity to highlight the research accomplishments of many of these past collaborators. Jim has reached and influenced thousands of students and young scientists, and he has made scientific discoveries and contributions to theory that will influence the field of ecology for generations to come. Through this special issue, we present a subset of these accomplishments.

Jim joined the biological sciences faculty at the University of Utah in 1977, the home of his 40+-year career. Jim and his extended research group of 38 postdoctoral scholars, 21 graduate students, countless undergraduate assistants, and numerous visitors and collaborators have garnered the respect of ecologists worldwide for "moving the dial" on many areas of ecological research from the evolutionary ecology of C3 and C4 photosynthesis, to the functional ecology of desert plants and plant communities, to the multifaceted ways stable isotope tools can be applied to explore questions in wildland and urban environments. Jim's early work taught us to think about plant energy balance in new ways and while doing so provided a range of insights into how plants cope with thermal and drought stress. Recognizing the powerful opportunities provided by stable isotope methods, Jim and his collaborators developed new approaches to understanding animal diet and patterns of migration, showed us new paths for advancing the reconstruction and patterns of climatic change, and helped shape and advance the emergent field of 'forensic ecology'. As an example of Jim's insight and leadership, and his passion not to just stay ahead of the curve but to draw the map, he recognized and practiced the art of rejuvenation through continual scientific

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reinvention. As a result, he led many of us into thinking about novel ways that the field of ecology could and should change, evolve, and expand. One outcome was the pivotal role Jim played in the development of the field of "urban ecology". Here, he brought his stable isotope expertise to bear on the topics of trace gas emissions, biogeochemical cycles, and natural resource management in urban and suburban ecosystems. He was also the first to establish a long-term, high-resolution, network for determining patterns in trace gas quantification and stable isotope composition, and to use that insight to partition greenhouse gas exchanges into specific sources and sinks at urban-to-regional scales.

The list of "firsts", honors and accomplishments that Jim has amassed is impressive. For example, in 1984, Jim opened, and continues to direct, one of the first research and training facilities called the SIRFER lab (Stable Isotope Ratio Facility for Environmental Research) focused on advancing the rapidly expanding field of isotope ecology. The research advanced at SIRFER in the late 1980s and early 1990s led to the genesis of a two-week intensive Stable Isotope Ecology and Biogeochemistry course (now known as IsoCamp) that has been offered every year since 1996. Faculty members in this course teach state-of-the-art approaches to the application of stable isotope tools, with updates on the most cutting-edge scientific questions, and provocations to imagine and address new questions and challenges. IsoCamp has had a tremendous impact on the field of stable isotope ecology and has helped train over 700 young national and international scientists from the next generation. This course was the reason the American Geophysical Union awarded Jim and his colleague Thure Cerling the Outstanding Education Program in Earth and Space Science award in 2017.

At the University of Utah, Jim was the first director of the University of Utah's Global Change and Sustainability Center, which has since grown to be an important hub for faculty and students to connect and collaborate around issues of global environmental change. Since 2000, Jim has been recognized as one of the University of Utah's Distinguished Professors as well as being honored with the Governors Medal for Science and Technology for the State of Utah. He is an elected fellow of the American Association for the Advancement of Science, the American Geophysical Union, and the Ecological Society of America, and in 2016 Jim was elected to be a Fellow in the prestigious US National Academy of Sciences. As this special issue is published, Jim will have amassed a peer-reviewed publication record of more than 500 papers with total citations of over 30,000 (Thomson-Reuters-Web of Science)—a rare and staggering accomplishment for any scientist!

The collection of contributed papers that follows highlights a range of subjects that Jim and his research group have helped advance over the past four decades. The authors have direct or indirect links to Jim as students, postdoctoral associates, collaborators, or the inspired recipients of Jim's insight. Jim and Darren Sandquist lead this issue off with an analysis of rare demographic scope, covering nearly 40 years of population dynamics and their relation to prominent climate cycles in three long-lived desert perennial shrubs. These authors describe the role of cyclic fluctuations in Pacific Ocean sea surface temperatures, and the mitigating influences of the desert topography, as key determinants of death and recruitment in an ecosystem that imposes unprecedented stochasticity in the availability of water and severe fitness costs to seedlings that cannot tolerate the unfavorable troughs of major climate cycles. This paper provides a unique insight that can only come from a dedicated commitment to collecting long-term data. From Jim and Darren's paper follows a suite of four papers that present a diversity of topics under the overarching umbrella of "global change science". The paper by Voelker, Roden, and Dawson highlights the results of an investigation that analyzed an 1100-year California Coast Redwood tree-ring isotope chronology. This unique analysis, which focuses on summertime hydroclimatic variability over the last millennium, reveals the importance of large scale (hemispheric) patterns of climatic change; but, surprisingly it does not record the mega-droughts seen in other climate proxies, including tree rings from other Western US species. Walker and Ward present a detailed look at the rise in CO_2 over the last century and disentangle the effects of a warming climate and CO_2 fertilization on reproductive phenology in plants from diverse populations of the model species, *Arabidopsis thaliana*. Their analysis concludes that CO_2 and temperature interact as global change drivers that have accelerated flowering times and increased plant size. This paper is also honored as an *Oecologia* Student Research Highlighted paper. An extension of these ideas is presented in the paper by Hultine, Bush, Ward, and Dawson, focusing on sexually dimorphic tree taxa where male and female plants can show marked differences in ecology and physiology. Under future climate change scenarios, such differences can result in imbalances in population-level sex ratios and therefore species-level fitness in the face of hydro-climatic change. Their review identifies genetic and trait-based strategies that should be adopted in future studies to resolve interactions between sex-dependent functional traits and climate change. The next paper by Tomas Domingues and colleagues is also couched in the context of climatic change but with a focus on multi-year droughts in Amazonian trees and the role that phenotypic trait plasticity plays in allowing trees to adjust to "new norms" in water availability. The results challenge the widely held view that because many Amazonian trees evolved under stable and favorable climatic regimes the degree of trait plasticity is limited when conditions such as drought occur. The next two papers in the issue then extend and build upon the evolutionary ecophysiology theme raised in the Domingues et al. paper. Sage, Monson, Ehleringer, Adachi, and Pearcy review recent advances in our understanding about the evolution and rise of C4 plants. By focusing on interactions among specific steps in the evolutionary remodeling of photorespiratory metabolism and changes in global climate and atmospheric CO_2 concentrations, they produce a synthetic view on past drivers that influenced evolutionary ecophysiology at the global scale and favored C4 over C3 plants in certain environments. Goud and Sparks explore how the use of carbon and nitrogen isotope data in a diverse group of plants in the family Ericaceae can be used to look at the roles of selection versus phylogenetic history in causing ecophysiological diversification in the group. Their analysis provides a powerful example of the advantages of combining C and N stable isotope analyses with phylogenetic insight to resolve the forces that shape trait diversification. In the paper by Flanagan and Flanagan, we transition to ecosystem-scale research and the interactions between seasonal precipitation distribution and CO_2 and energy exchange in a Sonoran Desert landscape dominated by saguaro cactus (one of the largest cactus species on earth) using crassulacean acid metabolism. They show that patterns of seasonal precipitation distribution, particularly during the summertime North American Monsoon, interact with temperature in shaping the patterns of NEE and the entire ecosystem carbon budget. We then turn to the paper contributed by Helliker and colleagues that integrates whole-canopy photosynthetic and energy balance assessments with measurements of the oxygen isotope composition of cellulose to resolve photosynthesis-weighted estimates of canopy temperature across a suite of forest types. Their studies show that the use of oxygen stable isotope composition in extracted cellulose provides promise for assessing seasonally integrated patterns of photosynthesis–temperature relations across broad geographic and climatic gradients. We then continue to explore the wide range of applications from stable isotope data for plant ecophysiological investigations. Jesperson, Leffler, Oberbauer, and Welker, for example, present the results of an investigation focused on leaf chemistry, carbon isotope composition, and the attribution of water sources using oxygen and hydrogen stable isotopes to assess plant performance in Arctic ecosystems where woody shrub expansion has been and continues to occur. They show the important role of snowpack-derived water in shaping shrub expansion dynamics. A focus on the roles hydrogen and oxygen isotope composition of water is expanded in the paper presented by Bowen and colleagues. They describe how specific isotope ratios can be used to deepen our understanding of evaporative processes that impact the water traced into aquifers, rivers, soils, plant source waters, and even beverages that have their origin from plant products. They provide a thorough synthesis of the topic and offer an analytical framework for better constraining the impact evaporation can have on source waters and the potential errors that can be incurred if accurate accounting does not determine evaporation in relation to local meteoric waters. In the paper that follows, Gerlein-Safdi, Gauthier, and Caylor explore how the isotopic compositions of source and leaf water can be used to better understand the role of foliar water uptake in a tropical plant species where leaf wetting events from dewfall are a common occurrence. They further explore how dew can impact both leaf energy balance and transpiration from wetting events. Tipple and Ehleringer then explore how the isotope analyses of specific compounds such as common alkanes can be used to elucidate different aspects of heterotrophic and autotrophic metabolism from a range of plant leaves. This sets the stage for more robust interpretations of leaf wax n-alkane isotope biomarkers in both modern and paleobotanical samples. We then turn to the application of stable isotope tools and data in animal ecology and forensic science. Chesson and colleagues provide an overview of how principles of isotope analyses, that had their origin in geochemistry, can be applied to a wide range of forensic investigations to determine the source of materials or the processes that act on those materials, and thus detect crimes of adulteration or counterfeiting. They specifically take up the issue of forensic support that is offered by mapping isotopic insight onto landscapes, the so-called ‘isoscapes’, to geolocate the origin of a sample of interest. These same types of tools are applied in the paper presented by Cerling and colleagues to enhance our understanding of the diet and movement ecology of the critically endangered black rhinoceros in Kenya; a beautiful example of how isotope tools and data can be used in a wildlife conservation context. With the continued threat of subspecies extinctions in African black rhinos, stable isotope tools used to understand diet and migration patterns will provide crucial support to future management decisions. And finally, in a paper presented by Smith, Williamson, Pataki, Ehleringer, and Dennison, we see again how the application of stable isotope tools, which formed the focus of so much of Jim’s career, can inform the nature of carbon, water, and nitrogen cycles in urban environments exposed to 50+ years of anthropogenic impacts. These authors show that interactions between soil biogeochemistry and the socioeconomic determinants of urban ecological dynamics can be understood through analysis of soil carbon to nitrogen ratios, isotopic composition, and gaseous losses of yards along a chronosequence. These are traditional approaches applied during studies of natural-system ecosystem ecology, but now targeted to understanding the role of humans in the biosphere.

The papers of this issue were invited and assembled with the intent of reflecting the multiple dimensions of Jim’s scientific impacts. We also want to take this opportunity to reflect on the many contributions that Edna Ehleringer has made as she helped support Jim’s students and postdocs, and helped mentor students to achieving success in both science and as engaged members of families and communities. Her support of students has been a key to Jim's success and for the broad success of many people who have spent time in his group. In closing, we thank all of those who enthusiastically stepped forward to make the concept of this special issue a reality. Their contributions and expressions of love and admiration toward Jim have spoken volumes about the profound influence one person can make on a generation of scientists. This issue is dedicated to Professor James R. Ehleringer, the amazing scientist, mentor, and friend who has impacted our lives, both within and beyond science.

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