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EDITORIAL

Celebrating 25 Years of ECOSYSTEMS

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As Co-editors in Chief of ECOSYSTEMS, we are delighted to celebrate the growth and success of this journal over the past 25 years. Ecosystem science remains a vibrant field within ecology, and ECOSYSTEMS is still the only journal exclusively devoted to this subdiscipline of ecology. The journal is now well-established as an outstanding international outlet for studies of the structure and function of terrestrial, aquatic and marine ecosystems across a wide range of spatial and temporal scales. Foundational texts in ecosystem ecology (for example, Chapin and others 2011; Weathers and others 2021) and landscape ecology (for example, Turner and Gardner 2015; With 2019) introduce students to the key concepts and research that underpin our discipline. In turn, ECOSYSTEMS communicates current advances in our science. Although nearly all ecological studies are conducted in an ecosystem, there is a fundamental difference between ecology **in** ecosystems versus the ecology **of** ecosystems (Fisher 1997). ECOSYSTEMS focuses on the latter, and here we briefly reflect on the past and look toward the future of the journal.

The year 1998 marked the launch of ECOSYSTEMS and publication of a landmark synthesis volume, SUCCESSES, FRONTIERS AND LIMITATIONS IN ECOSYSTEM SCIENCE (Pace and Groffman 2014). The ensuing 25 years have seen myriad advancements in ecosystem science, many of which have been published in ECOSYSTEMS. Special features in ECOSYSTEMS have addressed diverse contemporary topics, such as the conduct of interdisciplinary research, spatial variability in ecosystem function, interactions between ecosystem science and economics, large infrequent disturbances, resilience surrogates, and cross-scale interactions. The 25 most highly cited papers in ECOSYSTEMS (Table 1) reflect substantial progress in diverse lines of inquiry that include enhanced understanding of biogeochemical cycles and interactions among key elements including carbon, nitrogen, phosphorus and sulfur, from local to global scales (for example, Neff and Asner 2001; Chapin and others 2006; Cole and others 2007); theory and testing of ecological resilience (for example, Peterson and others 1998; Carpenter and others 2001); linkages between species and ecosystems (for example, Walker and others 1999; Naiman and others 2002; Lundberg and Moberg 2003); and ecological consequences of natural disturbances (for example, Paine and others 1998; Turner and others 1998). Citations accrue over time, so the most highly cited papers are usually from earlier years, but highly cited papers in ECOSYSTEMS from the past five years also reflect disciplinary advances. Notably, there is a rising emphasis on understudied habitats such as freshwater reservoirs (Prairie and others 2018), seagrass meadows in the Indian Ocean (Gullstrom and others 2018), and boreal forest headwaters (Ledesma and others 2018); increased representation of studies related to disturbance dynamics (for example, Guiterman and others 2018; van de Leemput and others 2018; Rhoades and others 2019); and a growing number of studies that incorporate ecosystem vulnerabilities to climate change (for example, Paquette and others 2018; Tucker and others 2019).

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Table 1. The 25 Most Highly Cited Papers in Ecosystems from Volumes 1–25

Authors (Year)	Title	Volume (Issue)	Citations*
Cole and others (2007)	Plumbing the global carbon cycle: integrating inland waters into the terrestrial carbon budget	10 (1)	2382
Holling (2001)	Understanding the complexity of economic, ecological, and social systems	4 (5)	1950
Carpenter and others (2001)	From metaphor to measurement: Resilience of what to what?	4 (8)	1790
McClain and others (2003)	Biogeochemical hotspots and hot moments at the interface of terrestrial and aquatic ecosystems	6 (4)	1557
Prasad and others (2006)	Newer classification and regression tree techniques: Bagging and random forests for ecological prediction	9 (2)	1329
Ehrenfeld (2003)	Effects of exotic plant invasions on soil nutrient cycling processes	6 (6)	1181
Gustafson (1998)	Quantifying landscape spatial pattern: What is the state of the art?	1 (2)	1070
Peterson and others (1998)	Ecological resilience, biodiversity, and scale	1 (1)	971
Levin (1998)	Ecosystems and the biosphere as complex adaptive systems	1 (5)	884
Chapin and others (2006)	Reconciling carbon-cycle concepts, terminology, and methods	9 (7)	710
Walker and others (1999)	Plant attribute diversity, resilience, and ecosystem function: the nature and significance of dominant and minor species	2 (2)	674
Paine and others (1998)	Compounded perturbations yield ecological surprises	1 (6)	679
Mekonnen and Hoekstra (2012)	A global assessment of the water footprint of farm animal products	15 (3)	602
Groffman and others (2004)	Calcium additions and microbial nitrogen cycle processes in a northern hardwood forest	9 (8)	553
Miller and others (2009)	Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountain, California and Nevada, USA	12 (1)	517
Turner and others (1998)	Factors influencing succession: Lessons from large, infrequent natural disturbances	1 (6)	515
Neff and Asner (2001)	Dissolved organic carbon in terrestrial ecosystems: Synthesis and a model	4 (1)	479
Foster and others (1998)	Land-use history as long-term broad-scale disturbance: Regional forest dynamics in central New England	1(1)	445
Naiman and others (2002)	Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems	5 (4)	419
Cotner and Biddanda (2002)	Small players, large role: Microbial influences on biogeochemical processes in pelagic aquatic ecosystems	5(2)	419
Navarro and Pereira (2012)	Rewilding abandoned landscapes in Europe	15 (6)	408
Bigler and others (2006)	Drought as an inciting mortality factor in Scots pine stands of the Valais, Switzerland	9 (3)	366
Lundberg and Moberg (2003)	Mobile link organisms and ecosystem functioning: Implications for ecosystem resilience and management	6 (1)	361
Groffman and others (2004)	Nitrogen fluxes and retention in urban watershed ecosystems	7 (4)	355
Schindler (1998)	Replication versus realism: The need for ecosystem-scale experiments	1 (4)	350

**Data obtained from Web of Science, 11 October 2022.*

In this special 25th anniversary issue of Ecosystems, we showcase illustrative examples of current research that continues to expand frontiers in ecosystem science. Several papers offer new insights into the fundamental structure and function of ecosystems. Mehner and others (2022) review trophic transfer efficiency in lakes and provide alternative approaches for its estimation. Cleveland and others (2022) synthesize understanding of the rates, patterns and controls on rates of nitrogen fixation of cryptic (non-symbiotic) nitrogen fixation in terrestrial ecosystems and identify research priorities. Douglas and others (2022) explore the ''hot spots and hot moments'' conceptual framing for denitrification in estuaries. Myrstener and others (2022) examine drivers of algal nutrient limitation in boreal to arctic streams and lakes. Two papers address applications in ecosystem ecology arising from advancements in quantitative approaches, and both provide entrées to these methods. Perry and others (2022) focus on deep learning and how these methods can lead to new insights in ecosystem ecology. Senf (2022) highlights new ways in which remote sensing technology continues to generate opportunities for assessing spatial and temporal dynamics of ecosystems across a range of scales. Three more papers illustrate studies of ecosystem structure and function in response to changing drivers, such as extreme weather and changing disturbance regimes in a warming world. Severe droughts are occurring more frequently and for longer duration in many parts of the world; Moreno-Fernandez and others (2022) explore drought-induced tree die-off in Mediterranean forests. Storms are also intensifying. Quebbeman and others (2022) quantified increased fluxes of greenhouse gases following Hurricane Maria, a category 4 storm that severely impacted Puerto Rico in 2017. Jaramillo and others (2022) documented a massive influx of litterfall, and the largest annual N flux in 25 years, after Hurricane Patricia (also a category 4 storm) made landfall in Jalisco, Mexico. Lastly, three papers illustrate new insights gained via synthesis efforts. Eldridge and others (2022) synthesized effects on hydrological processes of livestock grazing, finding increased sediment production and reduced infiltration while also detecting nuance based on vegetation and climate. Ball and others (2022) present a cross-system analysis of litter chemistry during decomposition that finds no evidence for convergence in litter chemistry through 70% of decay, underscoring the importance of local context. Peacock and others (2022) analyzed 30 years of data for a large watershed in Sweden to study change in C-N-P ratios from precipitation through the landscape to freshwaters and then to the sea. While certainly not comprehensive, this collection of recent papers well reflects the breadth of studies published in the pages of Ecosystems.

Along with advances, several areas of ecosystem science remain to be strengthened. We continue to lament the absence of rigorous training in ecosystem simulation modeling in most graduate programs, a shortcoming that has been noted for at least 20 years (Canham and others 2003). Despite the widespread use of models and model output (for example, global climate projections) and the need to rely on process-based models to anticipate no-analog futures, many early career ecosystem ecologists receive little exposure to systems ecology and modeling. A special feature in Ecosystems in 2017 addressed this topic (Turner and Carpenter 2017), yet the need persists. The dawn of big data also offers both opportunities and pitfalls for ecosystem science. Opportunities to analyze data seem almost endless, but the dangerous pitfall of downloading data in the absence of connections to the field is already problematic. Observations, natural history, and a feel for organisms and their environment foster intuition about how nature works, leading to fundamental research questions and testable hypotheses. Ecosystem ecologists need ''boots on the ground'' to complement their quantitative tools, and we must strive to provide field experience and quantitative skills to early career scientists. Lastly, and perhaps exacerbated by the COVID-19 pandemic, we see a pressing need for high-quality opportunities for ecosystem ecologists to interact, sharing ideas and experience. Since cessation of the biennial Cary Conferences that brought ecosystem scientists together to explore current topics, no professional meetings focus solely on ecosystem science. We see opportunity for ecosystem scientists with varied expertise and study systems to again meet to grapple with big-picture questions.

And what are the big-picture challenges facing ecosystem science today? Clearly, climate change will permeate nearly every aspect of our science in the decades ahead. Atmospheric CO_2 concentrations are higher than they have been in the past three million years. Climate change is altering ecosystem structure and function at rates not seen for thousands of years, and the consequences of global warming are already having profound effects on people and ecosystems. Rates of change continue to accelerate, and long-predicted effects are happening sooner than expected throughout the world. The hydrology of the planet is changing in ways that bring too much water too quickly to some areas while other regions remain parched. Food, energy and water security are already threatened in many locations. The melting of glaciers is raising sea level and amplifying coastal flooding, and permafrost melt is releasing ancient carbon to the atmosphere that further exacerbates global warming. Natural disturbance regimes are moving well beyond their historical ranges of variability. These and other ongoing changes underscore the increased likelihood for abrupt changes to occur in and among ecosystems, especially as multiple drivers interact in unexpected ways, previously unrecognized thresholds are surpassed, and novel ecosystem structures and processes emerge. At the same time, the rising proportion of world population living in cities highlights the need for greater emphasis on urban ecosystem ecology. Ecosystem scientists must double down on their efforts to understand and anticipate future consequences of these profound changes–many of which are already entrained for at least several decades–and explore strategies to mitigate or adapt to a changing world. This will require continued efforts to integrate models with landscape and long-term data and to conduct experiments at the scales of human use. Expanded collaborations with economic and social sciences, humanities, the public and decision-makers are required to support the transformations that will be needed for societies to persist through the global shifts now underway. We call for the community of ecosystem scientists to rise to these challenges and to continue using Ecosystems as an outlet for their best work.

Lastly, we convey our gratitude. The success of Ecosystems owes much to the excellent contributions submitted by authors and the tireless efforts and good judgement of the ecosystem scientists who serve as reviewers and subject editors. Nearly 200 scientists have served on the editorial board of Ecosystems since its inception (Table 2). We are extremely grateful for their service. We also have been most fortunate to work with our outstanding Managing Editor, Suzann McClenahan, in Madison for all 25 years of Ecosystems. Her deep knowledge of the publication process and her prompt responses to editorial board members and authors set a standard of collegiality and competence that has been essential for success of the journal. We are also grateful to the staff at Springer, especially Janet Slobodien, Executive Publisher for Life Science Journals, and Jeff Davis, Production Manager, for their ongoing support and professionalism. Journal production is a team process, and we thank all who have contributed to the success of Ecosystems.

Table 2. Nearly 200 Scientists from 22 Countries Throughout the World Have Served on the Advisory or Editorial Board of Ecosystems Since Its Debut in 1998

John Aber, USA
J. Marty Anderies, USA
Krister Andersson, USA
Amy Austin, Argentina
Marilyn Ball, Australia
Jennifer Baltzer, Canada
Richard Bardgett, UK
Jill Baron, USA
Frank Berendse, Netherlands
Fikret Berkes, Canada
Emily Bernhardt, USA
Brandon Bestelmeyer, USA
Dan Binkley, USA
Paul Bolstad, USA
Benjamin Bond-Lamberty, USA
Matthias Buergi, Switzerland
Paul Bukaveckas, USA
Stuart Bunn, Australia
Amy Burgin, USA
Ingrid Burke, USA
Klaus Butterbach-Bahl, Germany
F. Stuart Chapin III, USA
Marianne Clarholm, Sweden
James Clark, USA
Johan Colding, Sweden
Jonathan Cole, USA
Robert Costanza, USA
Kathryn Cottingham, USA
Wolfgang Cramer, Germany
Gretchen Daily, USA
Virginia Dale, USA
Margaret Davis, USA
Gerlinde De Deyn, Netherlands
Franciska De Vries, UK
Donald DeAngelis, USA
Henri DeCamps, France
Hazel Delcourt, USA
Nancy Dise, UK
Terry Done, Australia
Carlos Duarte, Spain
Hugh Ducklow, USA
David Ellsworth, Australia
James Elser, USA
Bridget Emmett, UK
Tim Essington, USA

Table 2. continued

Valerie Eviner, USA
Katherine Ewel, USA
Lenore Fahrig, USA
Paul Falkowski, USA
Jingyun Fang, China
Christopher Field, USA
Carl Folke, Sweden
Marie-Josee Fortin, Canada
David Foster, USA
Douglas Frank, USA
Jerry Franklin, USA
Victor Galaz, Sweden
Pablo Garcia-Palacios, Spain
Robert Gardner, USA
Christian Giardina, USA
Christine Goodale, USA
Christopher Gough, USA
Nancy Grimm, USA
Volker Grimm, Germany
Peter Groffman, USA
Katherine Gross, USA
Michael Gundale, Sweden
Lance Gunderson, USA
Stephanie Hampton, USA
Susan Hanna, USA
Stephen Hart, USA
Ashley Helton, USA
Jeffrey Hicke, USA
Thomas Hickler, Germany
Sabine Hilt, Germany
Sarah Hobbie, USA
Richard Hobbs, Australia
Crawford Holling, USA
Milena Holmgren, Netherlands
Robert Howarth, USA
Feng Sheng Hu, USA
Stephen Jackson, USA
Bengt-Owe Jansson, Sweden
Erik Jeppesen, Denmark
Mandy Joye, USA
Paul Kardol, Sweden
David Karl, USA
Sujay Kaushal, USA
Nicholas Kettridge, UK
Felix Kienast, Switzerland
Ann Kinzig, USA
Thomas Kitzberger, Argentina
Eric Lambin, Belgium
Michael Landry, USA
Sandra Lavorel, France
Kai Lee, USA
Rik Leemans, Netherlands
Ricardo Letelier, USA
Simon Levin, USA
Gene Likens, USA
Martin Lindegren, Denmark

Table 2. continued

Jianguo Liu, USA
Jacqueline Loos, Germany
Gary Lovett, USA
Jane Lubchenco, USA
Ariel Lugo, USA
Manuel Maass, Mexico
Michelle Mack, USA
Pamela Matson, USA
Timothy McClanahan, Kenya
Karen McGlathery, USA
Diane McKnight, USA
Samuel McNaughton, USA
Susanne Menden-Deuer, USA
Jean Paul Metzger, Brazil
Judy Meyer, USA
Wolf Mooij, Netherlands
Hal Mooney, USA
Akira Mori, Japan
Patrick Mulholland, USA
Seth Munson, USA
Robert Naiman, USA
Jason Neff, USA
Christer Nilsson, Sweden
Ian Noble, Australia
Annika Nordin, Sweden
Kiona Ogle, USA
Robert O'Neill, USA
Catherine O'Reilly, USA
Ted Ozersky, USA
Michael Pace, USA
Jose Paruelo, Argentina
John Pastor, USA
Elise Pendall, Australia
Steven Perakis, USA
Pablo Luis Peri, Argentina
George Perry, New Zealand
Debra Peters, USA
David Pimentel, USA
Gilles Pinay, France
Trevor Platt, Canada
Tobias Plieninger, Denmark
Sandra Postel, USA
Cindy Prescott, Canada
Edward Rastetter, USA
James Reichman, USA
Walter Reid, Malaysia
Kevin Rogers, South Africa
Emma Rosi, USA
Nigel Roulet, Canada
Osvaldo Sala, Argentina
Marten Scheffer, Netherlands
David Schindler, Canada
Daniel Schindler, USA
Mary Scholes, South Africa
Steven Seagle, USA
Rupert Seidl, Austria

Table 2. continued

Sybil Seitzinger, USA
Gaius Shaver, USA
Herman Shugart, USA
Whendee Silver, USA
Erica Smithwick, USA
Patricia Soranno, USA
Will Steffen, Sweden
Craig Stow, USA
Benjamin Sullivan, USA
Mike Swift, France
Heather Throop, USA
Klement Tockner, Germany
David Tongway, Australia
Merritt Turetsky, USA
Nico van Breemen, Netherlands
Sander van der Leeuw, France
Ellen van Donk, Netherlands
Tom Veldkamp, Netherlands
Peter Vitousek, USA
Brian Walker, Australia
Diana Wall, USA
Carl Walters, Canada
David Wear, USA
Carol Wessman, USA
Frances Westley, Canada
John Wiens, USA
Kimberly With, USA
Joy Zedler, USA

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