



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, *SUCCESSSES, 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 (Ledema 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).

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 CO₂ 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
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Benjamin Bond-Lamberty, USA
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Paul Bukaveckas, USA
Stuart Bunn, Australia
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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-Josée 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
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 Diana Wall, USA
 Carl Walters, Canada
 David Wear, USA
 Carol Wessman, USA
 Frances Westley, Canada
 John Wiens, USA
 Kimberly With, USA
 Joy Zedler, USA

REFERENCES

- Ball BA, Christenson LM, Wickings KG. 2022. A cross-system analysis of litter chemical dynamics throughout decomposition. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00749-6>
- Bigler C, Braker OU, Bugmann H, Dobbertin M, Rigling A. 2006. Drought as an inciting mortality factor in Scots pine stands of the Valais, Switzerland. *Ecosystems* 9:330–343.
- Canham CD, Cole J, Lauenroth WK, editors. 2003. *Models in ecosystem science*. Princeton (NJ): Princeton University Press. 504p.
- Carpenter S, Walker B, Anderies JM, Abel N. 2001. From metaphor to measurement: Resilience of what to what? *Ecosystems* 4:765–781.
- Chapin FS III, Matson PA, Vitousek PM. 2011. *Principles of terrestrial ecosystem ecology*. New York (NY): Springer. p 544p.
- Chapin FS III, Woodwell GM, Randerson JT, Rastetter EB, Lovett GM, Baldocchi DD, Clark DA, Harmon ME, Schimel DS, Valentini R, Wirth C, Aber JD, Cole JJ, Goulden ML, Harden JW, Heimann M, Howarth RW, Matson PA, McGuire AD, Melillo JM, Mooney HA, Neff JC, Houghton RA, Pace ML, Ryan MG, Running SW, Sala OE, Schlesinger WH, Schulze ED. 2006. Reconciling carbon-cycle concepts, terminology, and methods. *Ecosystems* 9:1041–1050.
- Cleveland CC, Reis RG, Perakis SS, Dynarksi KA, Batterman SA, Crews TE, Gei M, Gundale MJ, Menge DNL, Peoples MB, Reed SC, Salmon VG, Soper FM, Taylor BN, Turner MG, Wurzbacher N. 2022. Exploring the role of cryptic nitrogen fixers in terrestrial ecosystem: A frontier in nitrogen cycling research. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00804-2>
- Cole JJ, Prairie YT, Caraco NF, McDowell WH, Tranvik LJ, Striegl RG, Duarte CM, Kortelainen P, Downing JA, Middelburg JJ, Melack J. 2007. Plumbing the global carbon cycle: Integrating inland waters into the terrestrial carbon budget. *Ecosystems* 10:171–184.
- Cotner JB, Biddanda BA. 2002. Small players, large role: Microbial influences on biogeochemical processes in pelagic aquatic ecosystems. *Ecosystems* 5:431–435.
- Douglas EJ, Gammal J, Needham HR, Stephenson F, Townsend M, Pilditch CA, Lohrer AM. 2022. Combining techniques to conceptualise denitrification hot spots and hot moments in estuaries. *Ecosystems*. <https://doi.org/10.1007/s10021-021-00732-7>
- Ehrenfeld JG. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. *Ecosystems* 6.
- Eldridge DJ, Ding J, Travers SK. 2022. A global synthesis of the effects of livestock activity on hydrological processes. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00746-9>
- Fisher SG. 1997. Creativity, idea generation, and the functional morphology of streams. *J North Am Benthol Soc* 16:305–318.
- Foster DR, Motzkin G, Slater B. 1998. Land-use history as long-term broad-scale disturbance: Regional forest dynamics in central New England. *Ecosystems* 1:96–119.
- Groffman PM, Law NL, Belt KT, Band LE, Fisher GT. 2004. Nitrogen fluxes and retention in urban watershed ecosystems. *Ecosystems* 7:393–403.
- Guiterman CH, Margolis EQ, Allen CD, Falk DA, Swetnam TW. 2018. Long-term persistence and fire resilience of oak shrubfields in dry conifer forests of northern New Mexico. *Ecosystems* 21:943–959.
- Gullstrom M, Lyimo LD, Dahl M, Samuelsson GS, Eggertsen M, Anderberg E, Rasmussen LM, Linderholm HW, Knudby A, Bandeira S, Nordlund LM, Bjork M. 2018. Blue carbon storage in tropical seagrass meadows relates to carbonate stock dynamics, plant-sediment processes, and landscape context: Insights from the western Indian Ocean. *Ecosystems* 21:551–566.
- Gustafson EJ. 1998. Quantifying landscape spatial pattern: What is the state of the art? *Ecosystems* 1:143–156.
- Holling CS. 2001. Understanding the complexity of economic, ecological, and social systems. *Ecosystems* 4:390–405.
- Jaramillo VJ, Martínez-Yrizar A, Machado LI. 2022. Hurricane-induced massive nutrient return via tropical dry forest litterfall: Has forest biogeochemistry resilience changed? *Ecosystems*. <https://doi.org/10.1007/s10021-022-00770-9>
- Ledesma JJJ, Futter MN, Blackburn M, Lidman F, Grabs T, Sponseller RA, Laudon H, Bishop KH, Kohler S. 2018. Towards an improved conceptualization of riparian zones in boreal forest headwaters. *Ecosystems* 21:297–315.
- Lundberg J, Moberg F. 2003. Mobile link organisms and ecosystem functioning: Implications for ecosystem resilience and management. *Ecosystems* 6:87–98.
- McClain ME, Boyer EW, Dent CL, Gergel SE, Grimm NB, Groffman PM, Hart SC, Harvey JW, Johnston CA, Mayorga E, McDowell WH, Pinay G. 2003. Biogeochemical hotspots and

- hot moments at the interface of terrestrial and aquatic ecosystems. *Ecosystems* 6:301–312.
- Mehner T, Attermeyer K, Brauns M, Brothers S, Hilt S, Schamweber K, van Dorst R, Vanni MJ, Gaedke U. 2022. Trophic transfer efficiency in lakes. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00776-3>
- Miller JD, Safford HD, Crimmins M, Thode AE. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountain, California and Nevada, USA. *Ecosystems* 12:16–32.
- Moreno-Fernández D, Camarero JJ, García M, Lines ER, Sánchez-Dávila J, Tijerín J, Valeriano C, Viana-Soto A, Zavala MA, Ruiz-Benito P. 2022. The interplay of the tree and stand-level processes mediate drought-induced forest dieback: Evidence from complementary remote sensing and tree-ring approaches. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00793-2>
- Myrstener M, Fork ML, Bergström A-K, CallistoPuts I, Hauptmann D, Isles PDF, Burrows RM, Sponseller RA. 2022. Resolving the drivers of algal nutrient limitation from boreal to arctic lakes and streams. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00759-4>
- Naiman RJ, Bilby RE, Schindler DE, Helfield JM. 2002. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. *Ecosystems* 5:399–417.
- Navarro LM, Pereira HM. 2012. Rewilding abandoned landscapes in Europe. *Ecosystems* 15:900–912.
- Neff JC, Asner GP. 2001. Dissolved organic carbon in terrestrial systems: Synthesis and a model. *Ecosystems* 4:29–48.
- Pace ML, Groffman PM. 2014. Successes, limitations, and frontiers in ecosystem science. New York (NY): Springer. p 522p.
- Paine RT, Tegner MJ, Johnson EA. 1998. Compounded perturbations yield ecological surprises. *Ecosystems* 1:535–545.
- Paquette A, Vayreda J, Coll L, Messier C, Retana J. 2018. Climate change could negate positive tree diversity effects on forest productivity: A study across five climate types in Spain and Canada. *Ecosystems* 21:960–970.
- Peacock M, Futter MN, Jutterström S, Kothawala DN, Moldan F, Stadmark J, Evans CD. 2022. Three decades of changing nutrient stoichiometry from source to sea on the Swedish west coast. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00798-x>
- Perry GLW, Seidl R, Bellvé AM, Rammer W. 2022. An outlook for deep learning in ecosystem science. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00789-y>
- Peterson G, Allen CR, Holling CS. 1998. Ecological resilience, biodiversity, and scale. *Ecosystems* 1:6–18.
- Prairie YT, Alm J, Beaulieu J, Barros N, Battin T, Cole J, del Giorgio P, DelSontro T, Guerin F, Harby A, Harrison J, Mercier-Blais S, Serca D, Sobek S, Vachon D. 2018. Greenhouse gas emissions from freshwater reservoirs: What does the atmosphere see? *Ecosystems* 21:1058–1071.
- Prasad AM, Iverson LR, Liaw A. 2006. Newer classification and regression tree techniques: Bagging and random forests for ecological prediction. *Ecosystems* 9:181–199.
- Quebbeman AW, Menge DNL, Arellano G, Hall J, Wood TE, Zimmerman JK, Uriarte M. 2022. A severe hurricane increases carbon dioxide and methane fluxes and triples nitrous oxide emissions in a tropical forest. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00794-1>
- Rhoades CC, Chow AT, Covina TP, Feghel TS, Pierson DN, Rhea AE. 2019. The legacy of a severe wildfire on stream nitrogen and carbon in headwater catchments. *Ecosystems* 22:643–657.
- Schindler DW. 1998. Replication versus realism: The need for ecosystem-scale experiments. *Ecosystems* 1:323–334.
- Senf C. 2022. Seeing the system from above: The use and potential of remote sensing for studying ecosystem dynamics. *Ecosystems*. <https://doi.org/10.1007/s10021-022-00777-2>
- Tucker CL, Ferrenberg S, Reed SC. 2019. Climatic sensitivity of dryland soil CO₂ fluxes differs dramatically with biological soil crust successional state. *Ecosystems* 22:15–32.
- Turner MG, Baker WL, Peterson C, Peet RK. 1998. Factors influencing succession: lessons from large, infrequent natural disturbances. *Ecosystems* 1:511–523.
- Turner MG, Carpenter SR. 2017. Ecosystem modeling for the 21st century. *Ecosystems* 20:211–214.
- Turner MG, Gardner RH. 2015. Landscape ecology in theory and practice. New York (NY): Springer. p 482p.
- van de Leemput IA, Dakos V, Scheffer M, van Nes EH. 2018. Slow recovery from local disturbances as an indicator for loss of ecosystem resilience. *Ecosystems* 21:141–152.
- Walker B, Kinzig A, Langridge J. 1999. Plant attribute diversity, resilience, and ecosystem function: the nature and significance of dominant and minor species. *Ecosystems* 2:95–113.
- Weathers KC, Strayer DL, Likens GE. 2021. Fundamentals of ecosystem science. Waltham (MA): Academic Press. p 358p.
- With KA. 2019. Essentials of landscape ecology. Oxford (UK): Oxford University Press. p 641p.