Understanding Urban Ecology

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Editors

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An Interdisciplinary Systems Approach

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This book is dedicated to H. T. Odum, whose inspiration led to the development of ecological engineering, biophysical economics, ecological economics, ecological modeling, and emergy analysis, all of which apply ecology to understanding and solving environmental problems in human-dominated ecosystems. At least eight of the authors of this book are academic "children" or "grandchildren" of Dr. Odum.

We also owe a debt of gratitude to the small but highly influential band of the State University of New York College of Environmental Science and Forestry (SUNY-ESF) professors who, in the 1970s, laid the groundwork establishing the academic disciplines of urban forestry, urban meteorology, and urban soil science. They include Dr. Norman Richards, Dr. Rowan Rowntree, Dr. Lee Herrington, and Dr. Phillip Craul.

Preface

This textbook grew out of The Urban Initiative at SUNY College of Environmental Science and Forestry (SUNY-ESF), just as the new millennium was dawning (year 2000), which addressed the challenge of promoting environmental literacy in an ever-more urban world. Then President of ESF, Dr. Neil Murphy, stated:

> While many people associate the environment with wild lands and linked rural areas, the most important environmental and quality-of-life issues of the coming decades will be related to the urban environment.

A program in urban environmental science was intended to appeal to:

> All students, but perhaps especially those with an intimate knowledge of the challenges facing city inhabitants …. who can make professional contributions on issues ranging from urban forestry and urban wildlife to urban air and water quality, waste disposal, population growth and urban sprawl, sustainability assessment, and environmental justice and equity.

Faculty members felt that a course in Urban Ecology would provide students with the basic knowledge they would need to approach these issues from a systems perspective. The course was designed by an interdisciplinary team of natural and social scientists and faculty members from the Departments of Environmental *Chemistry*, Environmental and Forest *Biology*, *Forest* and *Natural Resource Management*, *Environmental Studies*, Environmental *Engineering*, and *Landscape Architecture*. The result is a field-based course that explores the metabolism of the city. Many of the authors of this book contribute lectures and field exercises to this course.

Understanding Urban Ecology: An Interdisciplinary Systems Approach originated from that effort and that course. The book and accompanying field labs are designed to help students at the college undergraduate level, or those in advanced-standing college-credit high school courses, understand urban environments as ecosystems. It also provides an overview for graduate students and a rich literature base on the topic. The ecosystem perspective, emphasized throughout, includes quantifying the flows of energy, nutrients, and materials required to make cities function, the controls on those flows imposed by nature and human decision-making, and the consequences to both biological and social quality of life that come from altering "natural" flows. Students are led to trace the flow and transformation of energy and

materials in, out, and within the urban ecosystem; the biophysical, social, and cultural factors that influence those flows; the resulting structure of the urban environment; and the environmental, economic, and social consequences of the structural and functional transformations that occur. Feedbacks, particularly those growing out of people's perceptions that influence decision-making by individuals, businesses, and government, are emphasized. Unlike most approaches to urban studies, the systems approach put forth in this book will give students not only a basic understanding of the fundamental importance of natural resources to the continued operation of cities and the effects of urbanization on hydrology, climate, air quality, etc. but also the tools to quantify and analyze the connections between the environmental and the socioeconomic subsystems of a city with the ultimate goal of assessing and generating sustainable urban systems.

The major organizing concept of this book is social-ecological metabolism, that is, the flows of biotic and industrial energy in the city and its surroundings. System "health" and "sustainability" are evaluated in terms of both social (S) and ecological (E) metabolism. The concept of metabolism and its associated properties allows evaluation of the many factors that contribute to an organism's or an ecosystem's biological health and can be used as a metaphor for society as a whole. The ecological analyses outlined in this book focus on the biophysical realm primarily in the form of energy, material, and nutrient inputs and outputs, derived "power" or "empowerment," and system waste. The social science perspective encompasses studies of both the cultural and economic components that comprise the human dimension of ecosystem processes and include primarily human perception and behavior, institutional behavior, societal cultural norms and preferences, and demographic and monetary flows. The S-component, like the E, is both a driving agent of urban ecosystem structure and function and receiver of impacts due to alteration of structure and function away from what we deem "natural" ecosystem processes. Because we take the view that humans are part of nature, we use "natural" to distinguish the qualities of ecosystem components like clean air and clean water, or ecosystem functions like the soil's ability to filter water, as they existed prior to human management and control. The demand by humans for an ever-more comfortable lifestyle, especially after the introduction of fossil fuels, has enormously accelerated the flow of nutrients and materials through the urban ecosystem, usually leading to stressed biological environments and the ecological conditions on which all species rely. The case is made that studying how nature works both with and without human intervention is vital to avoiding urban collapse and designing a sustainable future.

The chapters describe one by one the different subsystems of the urban environment, their individual components and functions, and the interactions among them that create the social-ecological environments in which we live. Purchase of the book will provide access to twelve detailed field exercises to promote hands-on experience, observation, and quantification of urban ecosystem structure and function so that students will be able to evaluate proposed policies for urban sustainability in terms of ecosystem capacity, potential positive and negative feedbacks, the laws of thermodynamics, and sociocultural perception and adaptability. The intent is to promote eco-consciousness based on natural science and empiricism rather

than intuition and sentiment, the latter of which often lead to counterproductive solutions to urban problems.

The book is structured as follows:

Part I of the book provides definitions of terms, the current global demographics with respect to urban growth, and the pressing issues faced by cities today. It builds the case for why urban ecology is increasingly important as a field of study. The authors present evidence to support our view that the urgent environmental and social issues of the future must be evaluated from an interdisciplinary systems approach if proposed solutions are to be sustainable and not cause nor contribute to counterintuitive effects in some other part of the system, now or in the future. The argument for viewing the city as an ecosystem, generally accepted among urban ecologists, with an emphasis on the social-ecological metabolism approach is presented because we believe it provides students the required base to understand how urban structure and function contribute to or detract from quality of life for both people and other urban dwellers.

Part II looks at the city in history from ancient times to the present. The authors describe the importance of geography, resources, and human decision-making to the metabolism of these cities, i.e., the growth and decline of urban economies. Both papers focus upon the role that energy plays in the development of complex social institutions and upon how a city was limited by the energy available to it. A fundamental transformation occurred in the eighteenth century when the access to fossil energy allowed the development of far greater degrees of complexity, greater specialization and the division of labor, and an expansion of debt to drive economic growth.

Part III chapters are intended to develop students' understanding of eight major social-ecological systems, their structure and function, how they control or are controlled by urbanization, and how they affect social-ecological metabolism *in* urban areas (microscale) and *beyond* (macroscale).

Part IV introduces concepts from land planning, landscape architecture, food studies, and ecological engineering that can help maintain ecosystem functions in the urban environment.

It is our hope that those who read this book will close the last page with a greater appreciation of the amazing complexity of the urban ecosystem, with a better understanding of how the biotic and abiotic components of the urban ecosystem interact and adapt (or fail to adapt) to changing conditions over time, and will be inspired to go out into the world and create novel solutions that will help make the cities of the future resilient to the environmental changes they are currently undergoing and will continue to encounter.

Electronic Supplementary Material

There are 12 labs or field exercises that accompany this text. All have been tested over the years in the Urban Ecology course taught at the State University of New York College of Environmental Science and Forestry. These exercises bring students into direct contact with the structure and function of the urban ecosystem and provide them with hands-on experience. All but two are conducted in the field, and most can be conducted over a typical 3-hour college lab period, two consecutive lab periods, or over a full day's excursion on the weekend. Not all chapters have an associated field exercise, but all chapters should be covered over the course to give students the fullest understanding of urban ecology. The exercises will need to be revised to the particular circumstances of the location where the course is taught. Although developed in a Northeastern US city, the activities can be adapted to any urban conditions and configurations. In some instances, equipment is recommended that may not be available. A clever instructor can devise an alternative means of gathering similar data or choose to leave out an element of the exercise. We hope you enjoy these excursions and the critical thinking required as much as our students have over the years.

Examples of the exercises and the chapter(s) they are best coordinated with are:

Field exercise	Field exercise description	Relevant chapters	Recommended site(s) to visit
1	Analysis of stream water quality along a rural to urban gradient using macroinvertebrates, chemical and physical analysis	1, 6	A stream or creek that flows from the rural environment to the city
2	Analysis of the metabolism of an urban block (Field Ex. 6 may precede)	2, 8	One city block, preferably mixed residential (single-family and apartment homes) and commercial establishments
3	Assessing community risk perception, beliefs, and attitudes	3, 13	Site to be determined based on issue and Institutional Review Board (IRB) permission
4	Urban hydrology and green infrastructure	6	Elements of the urban hydrological system, high points to low points, i.e., contributing zones, flooding zones; green infrastructure installations
5	Urban heat island assessment	7	Various urban sites with different quantities of built versus vegetated land cover
6	Measurement of urban trees to calculate air pollution removal capacity	8	Trees on an urban block or within a remnant urban forest (can be used as input to Field Ex. 2)

Field exercise	Field exercise description	Relevant chapters	Recommended site(s) to visit
7	Analysis of the urban nitrogen flux from the food table to the wastewater treatment plant to local receiving waterbodies	9, 14	Wastewater treatment plant; time permitting—a grocery distribution warehouse; the water body where the sewage effluent is dumped
8	Systems diagramming of the solid waste stream	10	A local waste to energy plant, or other solid waste disposal facility
9	Evaluation of the urban plant community across different biotopes	11	A lawn, wasteland, pavement cracks and walls, and/or park or residential garden, cemetery, downtown industrial landscape installation
10	Urban wildlife adaptation and evolution using *SquirrelMapper*	12	Computer lab
11	Assessment of an environmental justice claim using geographic information systems analysis	13	Computer lab
12	Lead levels in urban soils	13	Field and chemistry lab

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Anthony J. Brazel is an emeritus Professor in the School of Geographical Sciences & Urban Planning at Arizona State University (ASU). He is a geographer and climatologist focusing primarily at the urban and regional scale. While at ASU, he served as Arizona's governor-appointed state climatologist and manager of the Southwest Center for Environmental Research and Policy. Brazel is a former member of the Board of Urban Environments of the American Meteorological Society and a Scholarship Committee member of the International Association for Urban Climate. At ASU, he was an affiliate member of Sustainable Materials and Renewable Technologies Program (Julie Ann Wrigley Global Institute of Sustainability, EPA), member of the Climate Science Team of the Decision Center for a Desert City (NSF), and Co-PI of the Central Arizona-Phoenix Long-Term Ecological Research Project (CAPLTER, NSF). Brazel has been recognized with the International Association for Urban Climate's Luke Howard Award, the

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James P. Gibbs has degrees in Wildlife Management (University of Maine, BS, 1986), Ecology (University of Missouri, MA, 1988), and Forestry and Environmental Studies (Yale University, PhD, 1995). He is currently a SUNY Distinguished Professor at the State University of New York, College of Environmental Science and Forestry (SUNY-ESF) in Syracuse, New York, and adjunct scientist at the Galapagos Conservancy. He teaches courses each year in conservation biology and herpetology.

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Patrick Kangas is a systems ecologist with interests in ecological engineering, tropical sustainable development, and general ecology. He received his BS degree in Biology from Kent State University, MS in Botany and Ecology from the University of Oklahoma, and PhD degree in Environmental Engineering Sciences

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