Trophic Ecology

Bottom-Up and Top-Down Interactions across Aquatic and Terrestrial Systems

As researchers try to predict the effects of human modification at all trophic levels and mediate the impact of rapid environmental change, it has become clear that it is no longer a matter of agreeing that both bottom-up and top-down forces play important roles in diverse ecosystems. Rather, the question is: how do these forces interact across aquatic and terrestrial systems?

Bringing together the contributions of international experts in the field, this book presents a unique synthesis of trophic relationships within and across ecosystems that is a valuable foundation for the development of cross-system, multidisciplinary research. It also provides new insights into population biology and community ecology and examines the interactive effects of bottom-up and top-down forces on biodiversity at each trophic level.

A one-stop resource for learning about bottom-up and top-down interactions, this book encourages discussion and collaboration among researchers to identify similarities and differences in trophic interactions across aquatic and terrestrial systems.

Torrance C. Hanley is an aquatic community ecologist, whose research focuses on the role of diversity in trophic interactions in freshwater and marine systems. She is also interested in how inter- and intra-specific diversity of producer and consumer species impacts population and community dynamics, trophic interactions, and ecosystem function.

Kimberly J. La Pierre is a terrestrial community ecologist, whose research focuses on the effects of global change on trophic interactions and ecosystem function. She is also interested in drivers of plant invasions, including the role of herbivory and microbial mutualisms.

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Contents

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Preface

The idea for this book started as a series of lunch table conversations revolving around our respective research projects. Torrie's research at the time focused on trophic dynamics in lakes, looking at the interactive effects of food quality (specifically, algal carbon:phosphorus ratio) and predation on *Daphnia* life history and stoichiometry to better predict the effects of human modification of bottom-up and top-down forces in aquatic ecosystems. Kim's research examined the effects of nutrient availability and herbivore presence on grassland community composition and production across the broad precipitation gradient of the North American Great Plains. In discussing our respective studies, it became evident that our conversations about the interaction of bottom-up and top-down forces across aquatic and terrestrial ecosystems provided different perspectives and important insights that broadened our conceptual base and benefitted our research. This realization prompted us to organize a session for the annual meeting of the Ecological Society of America in 2011 to bring together aquatic and terrestrial ecologists studying the interaction of bottom-up and top-down processes in diverse ecosystems. During the session, similarities and differences in the strength and nature of trophic interactions across ecosystems became evident, stimulating dialogue between aquatic and terrestrial scientists. The success of this session and the satisfying exchange of ideas that resulted inspired this book.

The goal of this book is to provide a cohesive summary of the interaction of bottom-up and top-down processes across aquatic and terrestrial systems, which may serve as a basis for future cross-system studies examining patterns in these important drivers of community and ecosystems processes. In this book, the definitions of "bottom-up" and "top-down" are purposely broad to include a diverse group of studies and perspectives: bottom-up forces include nutrient and resource availability, and top-down forces include herbivores, predators, and parasites. Given the extent of human-induced global change, this topic is particularly timely and important. As we try to predict the effects of human modification at all trophic levels and mediate the impact of rapid environmental change, a better understanding of the interaction of bottom-up and top-down forces is instrumental to scientists and policymakers alike.

The independent effects of bottom-up and top-down forces are well understood in a diverse array of ecosystems. But it is widely accepted that trophic ecology is no longer a question of "bottom-up" or "top-down"; thus, it is important to examine how these often conflicting selection pressures interact, both in the laboratory and the field, to better understand the interactive effects of these factors in a variety of systems. The first section of this book ("Theory") describes the state of theory related to trophic interactions and highlights a number of approaches that apply across a wide variety of aquatic and terrestrial ecosystems, emphasizing the potential for cross-system comparison.

The second section of this book ("Ecosystems") focuses on aquatic and terrestrial ecosystems separately to clarify the state of our current understanding of trophic interactions in each system type and to highlight areas for future research. Each chapter describes the dominant bottom-up and top-down forces within the system and then explores the interaction of these factors and resultant effects on community and ecosystem processes. Despite the fact that this section is structured by ecosystem type, it begins to integrate across systems: Chapter 2 considers the strength and interaction of bottom-up and top-down processes in marine environments that range in scale from the open ocean to boundary upwelling systems to inland seas; Chapter 3 discusses bottom-up and top-down interactions in diverse freshwater environments, including ponds, lakes, streams, and rivers; Chapter 4 looks at trophic interactions in grasslands and savannas – related but distinct terrestrial environments; Chapter 5 compares the strength of bottom-up and top-down control in tropical and temperate forests; and Chapters 6 and 7 examine trophic dynamics at the aquatic–terrestrial border, including a diverse array of systems, such as lake-shore and stream-bank boundaries, the rocky intertidal, and salt marshes – all of which share important commonalities and differences.

The third section of this book ("Patterns and Processes") addresses how considering the interaction of bottom-up and top-down forces informs our understanding of a variety of ecological and evolutionary patterns and processes. In this section, each chapter focuses on a specific ecological or evolutionary process, comparing our current understanding of the role of trophic interactions in shaping these processes across ecosystems, and considering how these processes in turn shape trophic interactions. To facilitate communication across this extensive field, the chapters in this section encompass a broad range of aquatic and terrestrial ecosystems and cover a variety of observational, experimental, and theoretical approaches. First, the direct and indirect interactions of bottom-up and top-down forces are examined in detail: Chapter 8 highlights the importance of resource availability in mediating plant defenses in response to selection pressure from diverse consumers; and Chapter 9 discusses the role of herbivores and predators in determining nutrient cycling, and thus amounts and ratios of critical elements, such as carbon, nitrogen, and phosphorus. Next,

Figure 1 This image represents the challenges of considering the interaction of bottom-up and top-down processes across aquatic and terrestrial ecosystems; it illustrates the myriad components of aquatic and terrestrial food webs – including primary producers, consumers, and predators – the diversity of species within and across trophic levels and ecosystems, and the interconnectedness of these species, particularly at ecosystem boundaries. In addition, the image highlights the role of spatial scale (e.g., relative distance from the ecosystem boundary) and temporal scale (e.g., presence of diapausing eggs in the lake sediment) in trophic interactions, and most notably, it also represents the important similarities and differences that may emerge with cross-system comparisons of bottom-up and top-down processes.
(Credit: Tanya L. Rogers, Northeastern University.)

Chapter 10 describes an oft-overlooked but critically important component of the food web – namely, microbial and fungal processes – including consideration of how bottom-up and top-down forces may affect their role in trophic dynamics and how they in turn may affect trophic interactions in aquatic and terrestrial systems. The aim of the next chapters is to highlight less commonly considered factors that likely play a key role in trophic interactions and may greatly improve our understanding of trophic dynamics: Chapter 11 discusses how consideration of spatial and temporal scale informs our understanding of the strength and interaction of bottom-up and top-down forces across ecosystems; Chapter 12 highlights how species diversity, both within and across trophic levels, may influence the relative importance of bottom-up and top-down forces and ultimately affect the nature of their interaction; and Chapter 13 addresses the importance of evolution occurring at ecological time scales and how this may alter trophic interactions and impact community and ecosystem processes. Lastly, Chapter 14 tackles the all too timely topic of human-induced, global environmental change, including altered nutrient availability, climate change, loss of top predators, changes in biodiversity, and species invasions. Given the extent of anthropogenic modification of aquatic and terrestrial ecosystems, it is necessary to consider the interaction of multiple stressors and how they impact the interaction of bottom-up and top-down forces. Looking across systems to better understand these important drivers of community and ecosystem processes is a critical first step to predicting and mediating the effects of anthropogenic activities.

In sum, the goal of this book is to prompt more lunch table discussions, joint lab meetings, and collaborations looking at the interaction of bottom-up and top-down forces across aquatic and terrestrial ecosystems. While a lot of progress has been made since the old "bottom-up" or "top-down" debate, there is still much to be learned about trophic interactions in a variety of systems. Just as thinking about these processes in a different system has greatly benefitted our research and understanding of bottom-up and top-down interactions, we hope that this book will stimulate cross-system studies that continue to explore and identify key commonalities and differences in aquatic and terrestrial systems.

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