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The Value of Systems Thinking in a Rapidly Changing World

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What did you eat today? Whether it was a meal shared with family and friends or a quick bite on the go, the food choices you made connect you to a global web of growing, trading, cooking, and eating, with implications for your health, the environment, and plants, animals, and people all around the world. There is tremendous value in the ability to zoom out and see the broader picture, especially for complex problems like how to manage equitable, sustainable food systems. For example, if we are aware of how dynamics within a food system might influence the food choices available to us, we may view our roles in the system, both as consumers and as citizens, in different ways. In this issue of Lessons in Conservation, we focus on systems thinking and how and why ST can help us see the broader pictures, and hence help us understand and act on challenges all around us. The materials featured in this issue emerged from collaborations among multiple organizations and researchers focused on how to teach and assess systems thinking within interdisciplinary STEM education.* They are part of an ongoing effort to assemble a collection of different ST methods and approaches that can be used across a range of decision-making contexts from individual to societal levels.

Why Is Systems Thinking (ST) Important? Why Is ST Critical to the Future of Conservation and Related Fields?

It may be a cliché, but the world is indeed changing rapidly. In the 21st century, challenges are unfolding in a context that is potentially more volatile, uncertain, and complex than before (Game et al. 2013). Conservation challenges stem from drivers that are both social and environmental, and they are increasingly dynamic. If conservation practice is to be effective, it must engage with those social-economic contexts—and ultimately transform the societal systems that drive biodiversity loss (Díaz et al. 2019). This transformation, defined by Díaz and coauthors as "a fundamental, system-wide reorganization across technological, economic, and social factors" aiming to make sustainability the norm, requires a systems view and systems thinking.

Systems thinking is both a set of tools and a way of seeing. It should form part of how we conceptualize and investigate problems and make decisions in the field of conservation because many conservation issues are "wicked problems"; due to their complex and interconnected nature with other problems, they are difficult or impossible to solve. For example, despite our best efforts, we will not be able to solve the problem of species or habitat loss once and for all. But, we can think through the scope of these problems, how they form part of a system and how that system functions, try to understand the patterns and drivers in that system, and determine where we might intervene to make positive change. For example, the increase in emerging diseases we see today is linked to, and primarily driven by, human impacts on ecosystems. Through deforestation, road building, and mining, and through the production and trade of livestock, timber, agricultural, and other products, we are increasing our contact with wildlife and hence their pathogens. This contact becomes direct when humans trade wildlife and derived wildlife products, and the human activities that drive climate change and biodiversity loss also drive pandemic risk (IPBES 2020). It's become clearer than ever how environmental destruction and degradation, and the behaviors and underlying values and mindsets

*These collaborations include the Teaching Food Systems community of practice (https://www.ihn.cumc.columbia.edu/education/teaching-food-systems-community-practice-cop), as well as the team of researchers who led projects NSF DUE-1711260, and 1711411 Collaborative Research: Assessing "Systems Thinking" Skills and Learning in Interdisciplinary STEM Courses. For an example of project findings, see Gray et al. 2019.

that produce them, undermine our own well-being.

What is Needed, Especially in Teaching and Learning

Increasingly, we may find ourselves surrounded by the language of systems: "systems thinking," "systems approaches," "systems theory," "systems dynamics," "systems concepts," "systems science," "systemic change," "how to understand the system." Oftentimes the recognition that something is part of a system, or, more likely, of many nested systems, is an important first step towards deeper understanding of the linked social and environmental challenges we are trying to address. Systems thinking has been identified as a critical and important skill for conservation leaders in the 21st century (Bruyere et al. 2020), raising the question: how can we include it in our training and education, as we develop the leaders of the future? Navigating the evolving landscape of different approaches to teaching and learning about ST can be challenging and so, through this issue, we are bringing to the fore teaching materials to advance student ST skills that can be easily adapted for a range of different contexts, and a set of methods and tools that will expand as systems thinking is increasingly incorporated into our work and practices, in the classroom and beyond.

In this issue, we begin with a synthesis designed to be a succinct introduction to systems and systems thinking useful to any educators or students who are emerging systems thinkers. The synthesis reviews key questions a systems thinker asks, explores essential ST concepts, and provides brief descriptions of several ST frameworks and tools that can assist with: 1) understanding systems, 2) systems-oriented dialogue and reflection, and 3) co-designing responses that aim to promote system-wide change. The synthesis is accompanied by an adaptable presentation and teaching notes, which are available for educators to download at ncep.amnh.org. Two exercises leverage the content in the synthesis by focusing on two different ST tools: stakeholder analysis and a semi-quantitative modeling tool called Mental Modeler. Students use stakeholder analysis to explore a suite of issues ranging from public health initiatives like food labeling to human rights abuses in the fisheries industry, and use Mental Modeler to explore the current dynamics of and links between corn and beef production in the United States. These exercises, along with teaching notes that include information on assessment of ST in the Mental Modeler exercise, are the initial building blocks for a broader collection being assembled by NCEP that will include exercises on other ST tools, such as rich pictures.

Finally, this issue includes a set of materials on parasite biodiversity. The module (a synthesis and two exercises) focuses on introducing parasites and their ecological roles, yet they also demonstrate the importance of a systems lens. As the authors point out, more than 40% of known animal species are parasites, and while they are a major part of biodiversity they are seldom discussed in introductory biology courses. The exercises in this module bring students close to—even face-to-face with!—parasites, through a dissection activity that uses market-bought fish, and through the manipulation of real-world data on communities of parasites within coral reef fishes. Using these data, students explore whether and how human activity, specifically fishing, alters the number and type of parasites present within the fish.

Drawing from multiple examples, from the protozoan *Toxoplasma* to the Rinderpest virus, the Parasites Biodiversity Module illustrates how small or even microscopic parasites may have large effects on populations, entire ecological communities and, even global effects. These effects may unfold or increase over time—and ultimately even shape the evolution of species, both parasites and hosts. In this way, parasites help illustrate the importance of considering multiple scales, non-linear

dynamics, and time delays, all of which are important systems concepts. Importantly, the authors also highlight important questions to consider as we face a dynamic future, such as how host-parasite interactions will be changed by a changing climate, and by increasing levels of invasive species. Overall, this new set of teaching materials helps provide a broader view of ecosystems and food webs revealing hidden complexity, and increasing our understanding of ecological systems. As the authors point out, "parasites have important roles to play in ecosystems and we ignore them at our own peril."

Systems thinking is not a new idea. It is inherent to so many different (particularly Indigenous) knowledge systems and ways of knowing deeply embedded in cultures around the world that it often is not named as a distinct concept (Sterling et al. 2020). But systems thinking has been having a renaissance during recent decades, beginning with work on operations research, industrial dynamics, and computer modeling and simulation, and the understanding of what it means to "think in systems" is increasingly codified into books, websites, and curricula. In the past few years, fresh ideas have emerged about how some of the foundational concepts of systems thinking can help bring about new understandings about sustainability, equity, and social justice (Powell 2010; Valley et al. 2020). In conservation, and many other arenas, we increasingly see a need to understand and embrace complexity, and the importance of systems awareness to illuminating key underlying mindsets, values, and paradigms; to envisioning sustainable futures; to linking knowledge to action; and to identifying pathways for change. These approaches underpin effective transformations towards equitable sustainability.

We hope that this issue of Lessons in Conservation gives you the confidence to incorporate systems thinking into your teaching and assessment, if you haven't already, and some methods and tools to use in your classroom. Many of these tools have the added benefit of being able to integrate into remote teaching and learning as well because they employ open-access web-based platforms and activities suitable for small groups in breakout rooms. The year 2020 has presented all of us with challenges compounded by other challenges. Not only can systems thinking help us to make sense of the bewildering set of events of this past year, from a global pandemic to social and political turmoil, but can point us forward towards transformation.

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