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Ecology and Evolutionary Biology's Unique Contribution to Evaluation

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Background: Evaluation recognizes the need to consider three constructs – program change over time, the consequences of program action over time, and relationships between programs with their environments. Our methods for studying these constructs are home grown, i.e. they have developed almost exclusively within our field. These constructs, however, have a long and deep history in the fields of ecology and evolutionary biology (EEB). Thus, it makes sense to consider how EEB might contribute to the models. methodologies, and data analysis strategies that evaluation applies to program change, outcomes, and program/environment interactions. Further, in recent years evaluation has been paying ever greater attention to how complex system behavior affects programs and their outcomes. Much in the fields of EEB can be seen as a subset of complexity.

Purpose: This article has two purposes: 1) to convince evaluators that EEB can empower their efforts to evaluate change over time in programs, outcomes, and program/environment effects, and 2) to spur the growth of a group of evaluators with an interest in further exploring EEB's contribution to our field

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We contend that constructs from ecology and evolutionary biology (EEB) can contribute to evaluation in unique and powerful ways. An EEB lens can help us reconceptualize familiar evaluation scenarios; recognize evaluation possibilities that were previously hidden; suggest novel models, methodologies, and data interpretations; and lead to improved program design. However, it is one thing to argue that EEB concepts *can* provide novel evaluation insight. It is something else to argue that it is worth pursuing that insight.

In this article, we offer a brief overview of EEB and examine its contributions to date to evaluation and related fields. We then explore the potential for the broader application of EEB constructs in evaluation and suggest helpful criteria for evaluators to determine when an EEB lens may be especially useful. Finally, we offer a case study to illustrate how incorporating an EEB perspective into a government program evaluation helped to elucidate hidden and persistent challenges that threatened the program's sustainability, impact, and general contribution to the social good.

What Is Ecology and Evolutionary Biology?

EEB is widely considered an integrative discipline that explores the way organisms relate to their environment and change as conditions change. Merging the fields of ecology and evolutionary biology, EEB encompasses a broad array of interrelated subfields such as organismal biology, population genetics, and conservation. EEB seeks to understand how biological *systems* operate at various levels of organization—for example, organisms, populations, and ecosystems. EEB practitioners ask questions such as: How and why do these systems change, or adapt, over time (Collins, 1986; Heltne, 1998; McPeek & McPeek, 1996; Pastor, 2017)

While EEB is not exclusively focused on human-environment interactions, EEB researchers often explore how humans interact with the broader environment at various organizational levels (Heltne, 1998). Similarly, evaluators often explore how people interact at various, often nested, levels to understand how evaluands function. For example, many public health programs employ the socioecological framework to develop multilevel interventions that evaluators assess at the individual, interpersonal, and organizational levels (Bass & Krupp, 2010; Golden & Earp, 2012). Even so, many evaluators do not recognize the scientific foundations of this framework, which may inhibit them from taking advantage of the framework's full potential.

EEB's Application in Evaluation and Other Disciplines

EEB concepts have a track record of making explicit contributions to various disciplines.

Other Disciplines

Genetic algorithms have been applied to product design (Balakrishnan & Jacob, 1996) and software engineering (Boehm & Egyed, 1999). Selection and retention dynamics figure prominently in analyses of scientific knowledge development (Bradie & Harms, 2020a; Campbell, 1960) and technology (Basalla, 1988). Evolutionary constructs have been used to analyze the birth and extinction of organizational forms (Hannan & Freeman, 1989), and to understand organizational learning (Davies, 1998). West (2017) applied evolutionary theory in his transdisciplinary tome to study scaling across the life sciences, cities, economies, and corporations.

Evaluation

A subset of EEB's conceptual power has been sporadically applied specifically to evaluation. The genetic algorithm has been applied to participatory planning (Davies, 2020), as has the evolutionary adaptability of "failure" as a way to understand effective programming and planning (Davies, 2010). More broadly, Picciotto (2019) probed the implications of Campbell's evolutionary epistemology for evaluation theory.[1] According to Campbell, scientific progress itself evolves as selective pressure acts on a diversity of ideas. Extending this to evaluation, Picciotto argued that "the artificial selection process facilitated by evaluation is precisely designed to ascertain whether a [particular] social intervention … fits its operating and authorizing environment" (2019, p.

[1] Evolutionary epistemology is a naturalistic approach to knowledge change that emphasizes natural selection as a driver of new ideas, and the role of those ideas in an information environment. For an extensive treatment of this topic see Bradie and Harms (2023).

6).[2] Urban et al. (2014) also looked to evolutionary epistemology to propose "evolutionary evaluation" as a framework for understanding how programs—and groups of programs—develop over time. They present a cogent argument that evolutionary evaluation can help evaluators better align program phases with evaluation phases and types of validity, which can be vital to strategic decision-making.

EEB Applied to Commonly Asked Evaluation Questions

Table 1 contains questions that are familiar to evaluators, but which have dimensions that are unlikely to fully reveal themselves absent an EEB lens.

Table 1. Familiar Evaluation Questions that can Benefit from an EEB Perspective

No.	Evaluation question
1	How does the program change over time?
2	What unexpected consequences might arise?
3	Is the program robust, or might it fall apart easily?
4	What are the boundaries of the system I am evaluating?
5	What affects whether a program works in other settings?
6	What explains whether a program is sustained over time?
7	What were the fates of other programs with similar characteristics?
8	How does context affect the development of intended and unintended outcomes?
9	What is essential to the program, and what can vary without affecting its outcome(s)?
10	Are there other programs that compete for resources or pursue overlapping outcomes?
11	How do program parts (people, services, funding, etc.) influence each other, and how does that influence change over time?

Evaluators may ask, "What is it about EEB that adds value to evaluation as we currently practice it? Why not just stick with what we know we can do well? Why leap into unfamiliar territory?" The answer begins with an appreciation of concepts from EEB that are not present in evaluation, and which can direct evaluators' attention to aspects of those familiar questions that they would be unlikely to consider without thinking in terms of EEB (Table 2). (The coming case study provides some additional examples and elaboration of topics covered in the table.)

For the sake of clear explanation, the contents of Table 2 are presented as if each construct were independent of the others. They are not. For a systematic application of an EEB perspective it is necessary to combine constructs that are adjacent or overlapped. As an example, understanding the implementation of an innovative type of program (species) in a community (ecosystem) might require reasoning in terms of evolution, variation, adaptation, and rates of change. In fact, it is the common practice in EEB to combine constructs when theory and research are conceptualized. So too should it be when evaluators apply those constructs.

The examples in Table 2 provide innovative perspectives but are not completely alien to the evaluation community. Intellectual connections exist. One prominent example is the theme of variation in program characteristics that runs through many of the examples in the table. This theme echoes Rogers' (Rice & Rogers, 1980) seminal work on innovation adoption but invokes ways of reasoning about variation that are not familiar in common evaluation practice. A second example is "systems thinking" (Williams & Imam, 2007). EEB contains many constructs that are not found in systems thinking, but which are certainly congruent (Morell et al., 2024).

[2] Picciotto is referring to selection with respect to social interventions that are competing in an environment for recognition and resources.

Table 2. A Few Ecology and Evolutionary Biology (EEB) Constructs and Examples of their Applicability in Evaluation

EEB construct	Construct definition	Contributions to evaluative thinking
Diversity	In biology, the amount of variation present in a given ecosystem. More variation leads to greater diversity.	Attention to this concept directs attention to questions about diversity that go beyond who is involved in or benefits from a program and extend to the characteristics of programs themselves. *Examples of evaluation questions: How many different programs are operating? What are their essential differences? Why does this level of diversity exist? Do existing levels of diversity support or threaten program longevity?*
Evolution	Change in population gene frequencies over time.[a]	Understanding how innovative program changes thrive or wither over time leads to questions about the appearance of new programs, the extinction of others, change within existing programs, and fluctuation in species (program type) population size over time. *Examples of evaluation questions: What program variations have (by plan or accident) been tried? Which ones succeeded and which became extinct? How much change has happened over time? Are there any environmental dynamics (e.g., demand for a program's services, competition from new needs) to explain the changes?*
Variation	A difference or deviation (e.g., in structure, form, function) from the recognized norm or standard. In genetics, differences within and among species or a population.	Evaluators know that as programs are implemented, they often differ from each other, even when generally recognized as the "same" program. "Variation" within the EEB mindset moves this concept to a position of centrality when trying to understand species and populations. By embracing this mindset, evaluators are likely to confront many questions that they would usually ignore or gloss over. *Examples of evaluation questions: What are the common variants in programs designed to have the same functions? Do these variants affect characteristics such as a program's outcomes, efficiency, or adaptability to change? Are there subpopulations of similar reinventions?*
Adaptation	The process (or outcome) of adjusting structure, function, and/or behavior to better suit an environment.	Above, we identified "variation" as an EEB concept that can influence evaluative thinking. "Adaptation" raises follow-on questions about the process by which change comes about. *Examples of evaluation questions: What programs or program characteristics are most and least adaptive under current conditions? If conditions change, which characteristics will remain adaptive?*
Rates of change	How quickly various things change over time, irrespective of the magnitude of the change.	While not strictly a unique EEB construct, the investigation of rates of change frequently plays a critical role in EEB research. Evaluators who include rates of change add a critical temporal dimension to their work. *Examples of evaluation questions: How quickly is an innovation being adopted, irrespective of the number of adopters?*

Note. This table contains a small number of EEB constructs that we find useful for evaluation. For a comprehensive list of EEB constructs and their definitions, see https://www.biologyonline.com/.

[a] While programs do not contain genes that can mutate in a biological sense, they do contain internal characteristics that can be thought of *as if* they were genes that affect subsequent implementations, (i.e., generations) of a program.

Table 3. Some Intellectual Tools that Comprise a Research Tradition

No.	Intellectual tool
1	Research design
2	Interpreting data
3	Developing models
4	Defining data needs
5	Generating hypotheses
6	Assembling research teams
7	Identifying topics to research
8	Specifying acceptable answers
9	Constructing convincing arguments

Another reason to consider EEB in evaluation is that it gives evaluators a novel perspective on how the intellectual tools of inquiry are applied within a field's research traditions (Table 3). While each tool in the table has unique value, it is also true that all the tools are networked. Each has implications for the others, resulting in an emergent phenomenon—an approach to inquiry that is qualitatively different from its parts, unique to each field, and enlightening to practitioners from other fields. We are not advocating that evaluators become EEB researchers. Evaluation has its own history, reason for being, place in society, relationships with other fields, funding environment, and stakeholder base. But we do believe that select evaluations would gain value from considering the elements in Tables 2 and 3, and that the field of evaluation would become more useful to society if it inflected its work and its approach to problem-solving with an understanding of the EEB mindset.

When Is an EEB Lens Desirable?

An EEB lens becomes relevant for those working to evaluate a complex adaptive system (CAS)—a dynamic characterized by interrelated open networks of agents [3] united by a common goal (Carmichael & Hadžikadić, 2019; Preiser et al., 2018; Uhl-Bien et al., 2007).[4] The complex adaptive system criterion is important because such systems often display EEB behaviors.

When designing an evaluation, as part of their reflective practice, evaluators are likely to ask:

- Are relationships of central importance?
- Will the system change, or adapt, over time?
- Will feedback loops influence how things change?
- Is the system open, i.e., connected to the outside world?
- Will new properties emerge from complex interactions?
- Will the broader context influence how the system changes?

One could cogently argue that all programs are complex and that EEB will always influence the answers to these questions. This is true, but should that truth shape practical decisions? How will incorporating EEB affect timelines, costs, sampling, methodology, experts needed on the

[3] In the context of complex adaptive systems, an agent is an autonomous entity that can sense environmental conditions and follow specific rules based on those sensations. Agents can be any entity (e.g. people, group, organization) that can act as if it could "sense its environment" and "make a decision" based on those sensations.

[4] It would take this paper off in an entirely different direction to get into detail on this topic, but it is worthwhile for evaluators to appreciate the difference between agent-based (ABM) and system dynamic (SD) modeling (Parunak et al., 1998). (SD is also called equation-based modeling.) ABM focuses on the individual participants in a model. Those individual participants are given rules to guide their behavior, dropped into a environment, and allowed to interact. The aggregate consequences of those interactions generate the behavior of the model. SD is akin to classical statistics in that group behavior is what that matters, e.g., the average rate at which schools adopt a new reading curriculum. An important difference between the two kinds of modeling is that in ABM, local variation is respected because changes in one part of the model can result in changes in other parts of the model. System dynamic modeling only "cares" about group behavior, e.g., average rates, population sizes, and so on.

team, and ability to answer core questions of interest to the client? As evaluators contemplate these questions they need to consider whether and how EEB might affect their answers. Making such contemplation part of regular practice will help evaluators develop the discernment needed to decide whether invoking EEB constructs in an evaluation is worth the effort.

Of course, it is one thing for an evaluator to decide that EEB is worth integrating into an evaluation; it is quite something else to discuss the matter with clients. We recommend a variety of tactics, depending on how much the evaluator knows about the client. (We discuss these in our workshops on incorporating the dynamics of complex system behavior into evaluation [Morell, 2024]). The advice works for EEB as well. One possibility is to open the conversation with an EEB-type statement that may grab the client's attention. For instance: "This seems like a worthwhile program, but does it have any competition for resources in the community in which you plan to implement it (e.g. people's attention, available staff to hire)?" Or: "If we drop this program into a community and give it a high profile by putting heavy resources into it, what will happen to other programs that normally draw on the same resources?" Discussing questions like these can make for an effective segue into a fuller discussion of relevant EEB behavior. A second possibility is to ignore all discussion of EEB, but to incorporate its concepts into what looks like a garden variety evaluation. To build on the previous example, the matter of competition can be built into what looks like a familiar logic model. Clients may not question it, and never have to know that its inclusion in the model, and role in data interpretation, was inspired by a knowledge of EEB.

Case Study: Applying an EEB Lens to the Evaluation of a State Early Care and Education System

Here, we work through the implications of applying EEB to a real-life scenario. In it, we highlight knowledge that would be unlikely to derive from familiar evaluation approaches.

This scenario is based on evaluating a statewide intervention to improve early care and education (ECE) providers' nutrition and physical activity practices and environments in Arizona (LeGros et al., 2024). The state-supported Go NAPSACC [5] program was free to any interested ECE provider; providers could enroll online and progress through a site-level improvement process that included pre- and post- assessments. The state health department also trained a cohort of consultants representing various state and local agencies. Some sites qualified for additional technical assistance from these consultants.

During the initial program launch, ECE providers were offered small incentives to register their ECE sites in the program's online portal. In addition, a select group of ECEs were recruited into learning collaboratives that provided short-term technical assistance and more substantial funding. The overall goal was to grow the program over 3 years to be sustainable after the incentives expired. State leadership also envisioned that the program would operate synergistically with other state-sponsored ECE efforts.

Site-Level Evaluation

The Go NAPSACC program intervention included a built-in, evidence-based evaluation component to assess changes in the ECEs' practices and environment (e.g., How much indoor and outdoor play time is offered to children? How often do the ECE providers serve nutrient-rich vegetables?). [6] ECE providers completed a pre- assessment at the start of the improvement process and a post-assessment at the end.

Statewide Evaluation

Site-level data were aggregated to the state level to compare sites that received technical assistance versus no assistance, sites that participated or not in learning collaboratives, and other patterns in ECEs' participation over time. In general, ECEs in learning collaboratives were the most likely to complete the full cycle of improvement and see score increases. Descriptive statistics revealed that those paired with a trained consultant had higher rates of completing the post- assessment compared to ECEs without a consultant. However, there was high variability in ECEs' engagement in the improvement process. Aggregate scores across the state showed some statistically significant increases with medium to large effect sizes. Considering ECE providers individually revealed more nuance: Some providers showed score increases that reflected meaningful changes in real-world policies, practices, and environments; others showed no

[5] Nutrition and Physical Activity Self-Assessment for Child Care

[6] Assessment and improvement process details available at https://gonapsacc.org/.

change (or even decreases). Moreover, after the recruitment and learning collaborative incentives ended, consultants reported a noteworthy decline in ECE providers' interest in the program. As interest waned and the evaluator learned more about the state ECE system, the evaluator—who had prior academic training in EEB—began to notice parallels with EEB. This prompted her to incorporate an EEB lens into a subsequent mixed-methods evaluation (a continuation of the ongoing multi-year evaluation), which revealed that competing priorities and high ECE turnover threatened the program's sustainability.

What Can We Gain Using EEB Constructs?

Below, we demonstrate how five EEB constructs were applied to this ECE case scenario to better understand—and respond to—the program's evolution from its inception to its spread to its current "endangered" status:

1. Population. In EEB, a population is a group of organisms within a species that live and reproduce in a defined area. In the initial statewide evaluation, the evaluation was limited to assessing pre-post change at all sites and reporting those changes in aggregate. This failed to uncover differences in how and why the population responded to the intervention. Applying the population concept to the ECE scenario shifted the focus from the viability of any *one* site's program to the viability of the state-sponsored program *across the entire population* of ECEs while recognizing that each ECE interacted uniquely with the program. This stimulated new questions around the ecosystem, variation, selection, and adaptation.
2. Ecosystem. Shifting to an EEB lens primed the evaluator to more deeply explore how all participating ECEs were *interacting with* their broader ecosystem and the specific intervention. Indeed, the evaluator pivoted the evaluation approach away from a simple outcomes evaluation. Reframing the program as part of a complex adaptive system meant reframing the evaluation using a combination of systems and EEB approaches to elucidate how it was changing within the larger state ECE system. While landscape analyses take a similar approach, EEB provided a more comprehensive framework for understanding the ECE landscape as a dynamic, ever-changing network of interacting agents that are not static in time.
3. Variation. In EEB, mutation gives rise to variation, without which there would be no competition among variants. A well-known use of the mutation concept in the evaluation community is the aforementioned idea of evolutionary epistemology—a way of explaining the growth of knowledge (Bradie & Harms, 2020b; Picciotto, 2019). This approach posits that while the merit of an idea matters, it only matters with respect to its competition. Generalizing from new scientific ideas, evaluators can apply evolutionary epistemological thinking to a program's mission, goals, operational processes, and outcome possibilities. As the evaluator reconceptualized variation among the unique ECEs and various programs intended to support them, she began to ask deeper questions about which variants were present and how they arose. For example, she asked which health-related ECE programs were reaching which ECE providers, and where.
4. Selection. With EEB, what matters is the rate of growth and decline of *populations*, not individual organisms. One could argue that evaluators already deal with this matter because they calculate average performance across all population members. However, an evaluator taking an EEB-informed approach can combine the concepts of population, variation, and selection pressure from within the ecosystem to better understand which variants (ECE types and program characteristics) were more likely to grow or decline over time and under what conditions. For example, the evaluator began to uncover selective pressures that favored characteristics like program recognizability and licensing discounts but not ease of use or the availability of technical assistance consultants. Thus, it became clear that an evaluation designed to address these issues made it easier to identify and respond to present and emerging threats to the statewide program's existence, and to establish reasonable expectations for the rates of program implementation and expansion. Indeed, had these questions been asked from the start of the program, decision-makers may have been better poised to recognize and respond to selective pressures as they arose.
5. Evolution (coevolution). Evolution describes how populations change over time. Often, populations change with other populations as they influence one another. The analog in evaluation is a scenario in which the outcome of one program affects the viability of another. In the scenario presented here, leadership's

initial vision was that other state ECE programs would support the new program in mutually reinforcing ways, and under this assumption, the evaluator was only asked to gauge the success of the new program in isolation. However, this reasoning did not consider the potential for programs to coevolve. It was only through opportunistic feedback and years of experience that the evaluator learned the programs were often competing for the ECEs' limited time and resources. In response, the evaluator introduced the concepts of evolution and selective pressure into state ECE leaders' discussions. This led decision-makers to develop two models for future consideration: a "competition" model that allows for ECEs to select their preferred program(s) with the understanding that a widely unselected program may go extinct over time, and a "cooperation" model that calls on state agencies to redesign the state ECE system in a way that retains the most desirable program traits within fewer program options that mutually support one another. As of today, the state is piloting the cooperation model, and the evaluator is further investigating which program characteristics remain the more desirable.

Summary

We began this paper by asserting that applying an EEB lens can produce valuable knowledge that would not derive from commonly applied evaluation practices. As we put it, an evaluator might reason: "The words are different, but I could have done that. Why not stick to what I know?" To address this question, we began by offering a concise summary of EEB. We showed how it has been applied across a variety of disciplines, including evaluation, as in the integration of evolutionary epistemology and evolutionary evaluation. We also identified evaluation questions that would not likely surface using evaluative thinking as it is commonly practiced (Better Evaluation, 2023), but would be revealed with an EEB perspective. We suggested a reflective practice mindset to decide if and how EEB might be useful, and we recommended tactics for working with clients in terms of EEB. We then offered some key EEB theoretical constructs that underlie those evaluation questions. Finally, we offered a real-world case illustrating how EEB concepts reshaped an evaluator's sensitizing framework, foundational questions, methodologies, analyses, and interpretations.

Thought Experiment and an Invitation

Now that you have read our arguments for EEB's relevance, and the example we presented, what is your conclusion? Would an EEB lens provide a consequential addition to your evaluation practice?

As exposure to these ideas grows within our field, we invite those whose answer is "yes," regardless of your background or previous training, to join our evolving community of EEB-informed evaluators. An email to either of us will gain you admission. Lurkers and active participants are welcome. Together, we anticipate a deeper understanding of the EEB-evaluation connection and the development of novel applications. We also maintain a blog (https://evaluationuncertainty.com/) with a great deal of information on how EEB may be useful in evaluation. All are welcome to peruse its contents and to add comments and posts.

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References

Balakrishnan, P. V., & Jacob, V. S. (1996). Genetic algorithms for product design. *Management Science*, *42*(8), 1105–1117. www.jstor.org/stable/2634446

Basalla, G. (1988). *The evolution of technology*. Cambridge University Press. https://doi.org/10.1017/S0007087400044939

Bass, E. E., & Krupp, A. S. (Eds.). (2010). *Equity, social determinants and public health programmes*. World Health Organization. https://www.who.int/publications/i/item/9789241563970.

Better Evaluation. (2023). Evaluative Thinking. *Better Evaluation*. https://www.betterevaluation.org/tools-resources/evaluative-thinking

Boehm, B., & Egyed, A. (1999). Optimizing software product integrity through life-cycle process integration. *Computer Standards & Interfaces*, *21*, 63–75.

Bradie, M., & Harms, W. (2020a). Evolutionary epistemology. In E. N. Zalta (Ed.), *Stanford encyclopedia of philosophy*.

https://plato.stanford.edu/archives/spr2020/entries/epistemology-evolutionary/

Bradie, M., & Harms, W. (2020b). Evolutionary epistemology. In E. N. Zalta (Ed.), *Stanford encyclopedia of philosophy*. https://plato.stanford.edu/archives/spr2020/entries/epistemology-evolutionary/

Bradie, M., & Harms, W. (2023). Evolutionary epistemology. In E. N. Zalta & U. Nodelman (Eds.), *Stanford encyclopedia of philosophy* https://plato.stanford.edu/entries/epistemology-evolutionary/

Campbell, D. T. (1960). Blind variation and selective retentions in creative thought as in other knowledge processes. *Psychological Review*, *67*(6), 380–400.

Carmichael, T., & Hadžikadić, M. (2019). The fundamentals of complex adaptive systems. In T. Carmichael, A. J. Collins, & M. Hadžikadić (Eds.), *Complex adaptive systems: Views from the physical, natural, and social sciences* (pp. 1–16). Springer International Publishing. https://doi.org/10.1007/978-3-030-20309-2_1

Collins, J. P. (1986). Evolutionary ecology and the use of natural selection in ecological theory. *Journal of the History of Biology*, *19*(2), 257–288. https://doi.org/10.1007/BF00138879

Davies, R. (1998). *Order and diversity: Representing and assisting organisational learning in non-government aid organisations.* [Doctoral dissertation, University of Wales Swansea]. http://www.mande.co.uk/wp-content/uploads/1998/Davies-R-1998-PhD-Thesis.pdf

Davies, R. (2010). *Do we need a required level of failure (RLF)?* https://mandenews.blogspot.com/2010/10/do-we-need-minimal-level-of-failure-mlf.html

Davies, R. (2020). *ParEvo—a planning tool.* https://mscinnovations.wordpress.com/

Golden, S. D., & Earp, J. A. L. (2012). Social ecological approaches to individuals and their contexts: Twenty years of health education & behavior health promotion interventions. *Health Education & Behavior*, *39*(3), 364–372. https://doi.org/doi:10.1177/1090198111418634

Hannan, M. T., & Freeman, J. (1989). *Organizational ecology*. Harvard University Press.

Heltne, P. (1998). Basic concepts of ecology and evolutionary biology. *Hastings Center Report*, *28*(6), s12–s22. https://doi.org/10.2307/3528275

LeGros, T., Jacobs, L., Bhakta, A., & Orzech, K. (2024). *AZ Health Zone FY23 annual evaluation report: Reflecting community through the SNAP-Ed Window* [pages 18–23]. https://nutritioneval.arizona.edu/sites/nutritioneval.arizona.edu/files/materials/0%20FY23%20Annual%20Evaluation%20Report%20v1.0.pdf

McPeek, M. A, & McPeek, T. E. (1996). Evolutionary biology and community ecology. *Ecology*, *77*(5), 1319-1320.

Morell, J. A. (2024). *Early childhood development action network Master class in systems thinking: Complex system behaviors that can help us plan and evaluate*. https://evaluationuncertainty.com/2024/04/23/early-childhood-development-action-network-master-class-in-systems-thinking-complex-system-behaviors-that-can-help-us-plan-and-evaluate/

Morell, J. A., LeGros T., & Joseph, J. (2024). *More powerful evaluation by linking systems thinking with ecology and evolutionary biology*. https://evaluationuncertainty.com/2024/01/18/more-powerful-evaluation-by-linking-systems-thinking-with-ecology-and-evolutionary-biology/

Parunak, H. V. D., Savit, R., & Riolo, R. L. (1998). Agent-based modeling vs. equation-based modeling: A case study and users' guide. *Proceedings of Multi-Agent Systems and Agent-Based Simulation (MABS'98),* LNAI 1534, 10–25.

Pastor, J. (2017). Ecosystem ecology and evolutionary biology, a new frontier for experiments and models. *Ecosystems*, *20*(2), 245–252. https://doi.org/10.1007/s10021-016-0069-9

Picciotto, R. (2019). Donald T. Campbell's evolutionary perspective and its implications for evaluation. *Journal of MultiDisciplinary Evaluation*, *15*(33), 1–15.

Preiser, R., Biggs, R., De Vos, A., & Folke, C. (2018). Social-ecological systems as complex adaptive systems organizing principles for advancing research methods and approaches. *Ecology and Society*, *23*(4). https://www.jstor.org/stable/26796889

Rice, R. E., & Rogers, E. M. (1980). Reinvention in the innovation process. *Knowledge*, *1*(4), 499–514. https://doi.org/10.1177/107554708000100402

Uhl-Bien, M., Marion, R., & McKelvey, B. (2007). Complexity leadership theory: Shifting leadership from the industrial age to the

knowledge era. *The Leadership Quarterly*, *18*(4), 298–318. https://doi.org/DOI:10.1016/j.leaqua.2007.04.002

Urban, J. B., Hargraves, M., & Trochim, W. M. (2014). Evolutionary evaluation: Implications for evaluators, researchers, practitioners, funders and the evidence-based program mandate. *Evaluation and Program Planning*, *45*, 127–139.

West, G. (2017). *Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies*. Penguin.

Williams, B., & Imam, I. (2007). *Systems concepts in evaluation*. EdgePress of Inverness.