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PERSPECTIVE

Innovation in Practice

The Extinction Solutions Index (ESI): A framework to measure solution efficiency to address biodiversity loss

Rachel N. Martin[1] | Paul M. E. Bunje[1] | Alex O. Dehgan[1,2]

[1]Conservation X Labs, Washington, District of Columbia, USA
[2]Julie Ann Wrigley Global Futures Laboratory, Arizona State University, Tempe, Arizona, USA

Correspondence
Rachel N. Martin
Email: rachel@conservationxlabs.org

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Abstract

1. The field of conservation science has been described as a crisis- and solutions-oriented discipline, with roots as a problem-solving field. Despite this vision, current conservation research focuses on identifying and prioritizing high-risk species and regions rather than urgently solving the causes of biodiversity loss. While understanding human impacts on biodiversity and documenting the decline and rarity of species has been the basis of conservation science and is necessary, it is not sufficient to achieve global conservation targets nor match the speed and scale of current biodiversity loss.
2. Rather, conservation science must shift to a multidisciplinary approach that identifies and quantitatively evaluates high-impact solutions, providing evidence for which interventions will yield maximum benefits at scale. Adjacent sectors, like climate and international development, have created successful frameworks for ranking and evaluating solutions that conservation can incorporate and build upon.
3. This perspective introduces the Extinction Solutions Index (ESI), a framework designed to evaluate, compare and rank the most effective and efficient solutions to the biodiversity crisis. Inspired by Project Drawdown for climate solutions, the ESI aims to identify solutions across sectors and at different scopes of societal intervention—including those upstream of direct harm—and prioritize those with the highest-impact on the extinction crisis.
4. *Solution*. This approach can (1) identify the universe of interventions in myriad sectors of society and the economy that can curtail the threats leading to extinction, (2) develop a quantitative method to identify the highest-impact solutions to address biodiversity loss and (3) create a ranking architecture that integrates factors such as return on investment of solutions. The outcomes of the ESI will enable organizations, governments, businesses and funders to focus resources, activities and investment on the most impactful, scalable solutions.

KEYWORDS
causal threat models, global biodiversity loss, intervention evaluation, socioeconomic effects on ecosystems, species extinction

1 | INTRODUCTION

The world is currently experiencing an extinction crisis, with nearly one million plant and animal species threatened with extinction in the coming decades (IPBES, 2019). The global drivers of biodiversity loss, changes in land and sea use, direct exploitation of organisms, climate change, pollution and invasion of alien species, are far outpacing our ability to prevent the destruction of wildlife and ecosystems (Cowie et al., 2022; Edgar et al., 2023; IPBES, 2019). Together, these observations point to the advent of a sixth mass extinction (Ceballos et al., 2020; Cowie et al., 2022), one caused by a single species: *humans*. We have failed, as a planet, to meet any of the Aichi Biodiversity Targets this decade (Secretariat of the Convention on Biological Diversity, 2020) and must now reckon with this history as we forge ahead on the new Kunming-Montreal Global Biodiversity Framework.

While humans have created the problem, we also present a unique opportunity to solve it.

Conservation efforts must start addressing the underlying drivers of biodiversity loss, rather than just the symptoms, and advance solutions that can protect biodiversity at scale and minimize extinction risk. To do so, we envision a framework to rank, evaluate and compare solutions for biodiversity loss—an Extinction Solutions Index (ESI). Inspired by Project Drawdown (Hawken, 2017; Project Drawdown, 2024), which ranks and evaluates solutions to global climate change across different sectors and in different socioeconomic domains, the ESI seeks to evaluate, compare and rank the most effective and efficient innovations or interventions that would dramatically curb the sixth mass extinction while ensuring global human well-being.

2 | KEY ELEMENTS FOR AN ESI

Developing the ESI requires a framework that (1) identifies the landscape of solutions that have an impact on extinction—including those outside of the traditional conservation scope of solutions like protected areas—by targeting key drivers that ultimately lead to population decline and vulnerability to extinction, (2) develops a quantitative method to identify the highest-impact solutions over time and (3) creates a ranking architecture that integrates factors such as return on investment in order to make informed resource-dependent decisions. To do so, we have highlighted the crucial foci, principles and features of an ESI that will be critical to develop this global repository of solutions to biodiversity loss.

As we develop this Index, we intentionally emphasize solutions to the causes of extinction, that is the drivers of changes to natural systems, habitats and populations that ultimately lead to increased likelihood of species extinction, rather than other measurements of environmental impact. The ESI inverts the common assessment of biodiversity loss to quantify the interventions that will reduce such loss. This has the benefit of being both measurable with respect to an absolute impact—extinction is forever (de-extinction notwithstanding)—as well as capturing solutions to the broadest conception of the global biodiversity crisis, namely the sixth mass extinction. Furthermore, the ESI will aim to measure the collective impact of solutions on biodiversity loss at a systems level (e.g. extinction at the level of the ecosystem or biome), equivalent to the gigaton measurement for greenhouse gases. Rather than focusing on individual species, this approach seeks to capture system-level changes and identify actors that have the agency to implement these solutions at scale. Considering the lack of data on most species or their ecological functions, solutions with the ability to reduce extinction risk among the largest number of species and clades are likely to capture solutions to other aspects of biodiversity loss, including ecosystem function.

Despite its complexity, the urgent reality of extinction demands action. Yet, this imperative is hindered by an alarming funding gap for nature, perpetuating species declines across every corner of our Earth (Deutz et al., 2020; United Nations Environment Programme, 2023). While conservation efforts have long prioritized species endangerment such as Red Lists (IUCN, 2022) or regional importance via hotspots (Myers et al., 2000; Reid, 1998), the same vigour has not been applied to creating solutions that would remove the pressures off the underlying drivers. Here, we present seven key conceptual features of the ESI that are crucial in defining the next decade of conservation action and developing a set of solutions framed to solve this issue.

1. *Remove the pressures from the system*: To be effective, we need to reduce the threats to nature, such as land/sea use change, exploitation, climate change, pollution and invasive alien species (IPBES, 2019). We must enumerate the specific causes of those global drivers, explore how economic sectors are causing changes and prompt appropriate responses (i.e. replace/reduce/eliminate the negative action) by actors best positioned to enact change and alleviate threats, fostering tangible, transformative outcomes.
2. *Focus on scaling impact*: Conservation funding is often driven by philanthropy or bilateral and multilateral funding, which can be fickle, faddish and inconsistent, resulting in ineffective efforts that fail to reach a large number of species necessary to achieve impact at scale (Redford et al., 2013). To achieve significant impact, we need financially and ecologically sustainable solutions that can endure without constant philanthropic funding. By systematically designing interventions, starting from core assumptions, applying design principles and testing prototypes, we ensure better scalability of solutions that align with markets and consider human behaviours. This approach facilitates scaling both current effective solutions and those viable for the future (Dehgan & Hoffman, 2017).
3. *Look broader than conservation*: Traditional conservation efforts (e.g. protected areas, Key Biodiversity Areas and Red Lists) have had some success in preventing extinctions (Bolam et al., 2021). However, they have not kept pace with the current speed and scale of biodiversity loss, as many extinction drivers are beyond the scope of conservation alone. To effectively address this challenge, solutions must go beyond just establishing new reserves.

We need systemic, transformative changes that tackle multiple drivers of decline and benefit various species. These solutions may emerge from adjacent fields like food security, supply chain traceability, materials science, behavioural economics and international development, offering potential remedies not only for biodiversity loss but also for broader planetary challenges.

4. *Integrate existing metrics for comparison*: To compare diverse solutions effectively, we need a way to measure their impact on extinction, adaptable to interventions with varied operations and causal proximity to biodiversity loss. Given the lack of a universal metric such as no CO_2e for climate change and the complexity of ecological and socioeconomic dynamics driving biodiversity loss, we advocate prioritizing a practical set of metrics over a singular universal metric. These metrics should integrate into existing frameworks and research to make prioritization within existing systems as easy as possible (Zhu et al., 2024).
5. *Focus on evidence-informed approaches*: We need to know (1) these solutions exist today, and (2) that they have evidence of their performance, effectiveness or potential impact. This requires quantifiable information on the effectiveness of solutions in combating biodiversity loss that can be aggregated to address the global scale of species extinction. This evidence should draw from academic literature but can also be derived from unconventional sources such as patents, grant applications and prize competitions, unlocking additional solution sets. Solutions informed by expert input should be backed by appropriate data quantification to gauge their impact.
6. *Measure solution costs, benefits and efficiency*: By quantifying the costs of a solution, you create opportunities for innovation and prioritization (Wu & Pagell, 2011). Understanding the cost, benefits and ultimately the efficiency of a conservation solution not only allows for an accurate representation of its full scope, but it also enables comparisons across solution types for those wishing to invest in the space. This allows investors, businesses, philanthropies and organizations to make informed decisions about spending trade-offs.
7. *Utilize cutting-edge technology and experimentation*: Rapid advances in the use of technology in conservation ('nature tech') create both new solutions, including for both voluntary and involuntary transparency, as well as offer new ways of measuring the actual impacts of solutions, and improving upon them. While conservation has been slower than other fields, like global health, to harness emerging technologies, we believe these technologies provide entirely new classes of solutions that can change the reality of what is possible (Pimm et al., 2015). A key concept of the ESI is to be a tool that is used and updated to incorporate advances in these areas.

2.1 | Finally, the ESI must be a practical triage tool

The ESI aims to be user-designed for various actors (businesses, industries, communities and governments), bridging the gap between corporate disclosure and international conservation goals like those in the Global Biodiversity Framework (Zhu et al., 2024). Focused on extinction, it provides a target for collective action, such as Target 4 in the Global Biodiversity Framework, aiming to halt human-induced extinction by 2030 (CBD, 2022). It organizes solution sets around drivers of biodiversity loss and associated economic sectors contributing to species extinction to engage a larger portion of society as actors. Ultimately, this tool should enable triage (urgent actions to halt biodiversity loss) and guide decision-making on program prioritization, funding and the development of future technologies and practices.

3 | INCORPORATION OF EXISTING GLOBAL FRAMEWORKS, METRICS AND MODELS

In scoping the ESI, we have drawn insights from several existing solution and evidence evaluation frameworks. These include Project Drawdown, which offers a structured approach to categorizing solutions around emissions reduction, carbon sink enhancement and societal advancement, along with scenario planning to assess uptake rates and cost-effectiveness (Hawken, 2017; Project Drawdown, 2024). Similarly, 50 Breakthroughs by the Institute for Transformative Technologies has guided our considerations regarding deployment constraints, scalability and alignment with international sustainability objectives such as the UN Sustainable Development Goals (Institute for Transformative Technologies [ITT], 2019). One Earth's Solution Taxonomy (One Earth, n.d.) and Project Drawdown's organizational framework (Hawken, 2017; Project Drawdown, 2024) provide, existing, established structures for categorizing and integrating solutions for inspiration. Additionally, Conservation Evidence informs our understanding of expert-led actions, evidence quality, and trade-offs (Conservation Evidence—Site, 2020). Table S1 showcases a selection of metrics, models and frameworks that provide the technical foundation for measuring the impact of biodiversity interventions, complementing the broader array of metrics, indexes and indicators available for assessing environmental change (Marshall et al., 2020; Santini et al., 2017; Skidmore et al., 2015; UNEP-WCMC, 2024; Zhu et al., 2024).

Each of these initiatives has a ranking, organizing hierarchy or evaluation feature about them, and a compiled list of solutions or interventions that can inform the ESI framework.

4 | AN ESI: IDEAS, CHALLENGES AND MINIMUM VIABLE PRODUCT

These features from existing solution-oriented initiatives have been incorporated into an initial, high-level framework to organize solutions addressing global biodiversity loss (Figure 1). This initial ESI framework captures solutions that (1) reduce threats to biodiversity and take pressures off the system (i.e. ameliorate the underlying drivers

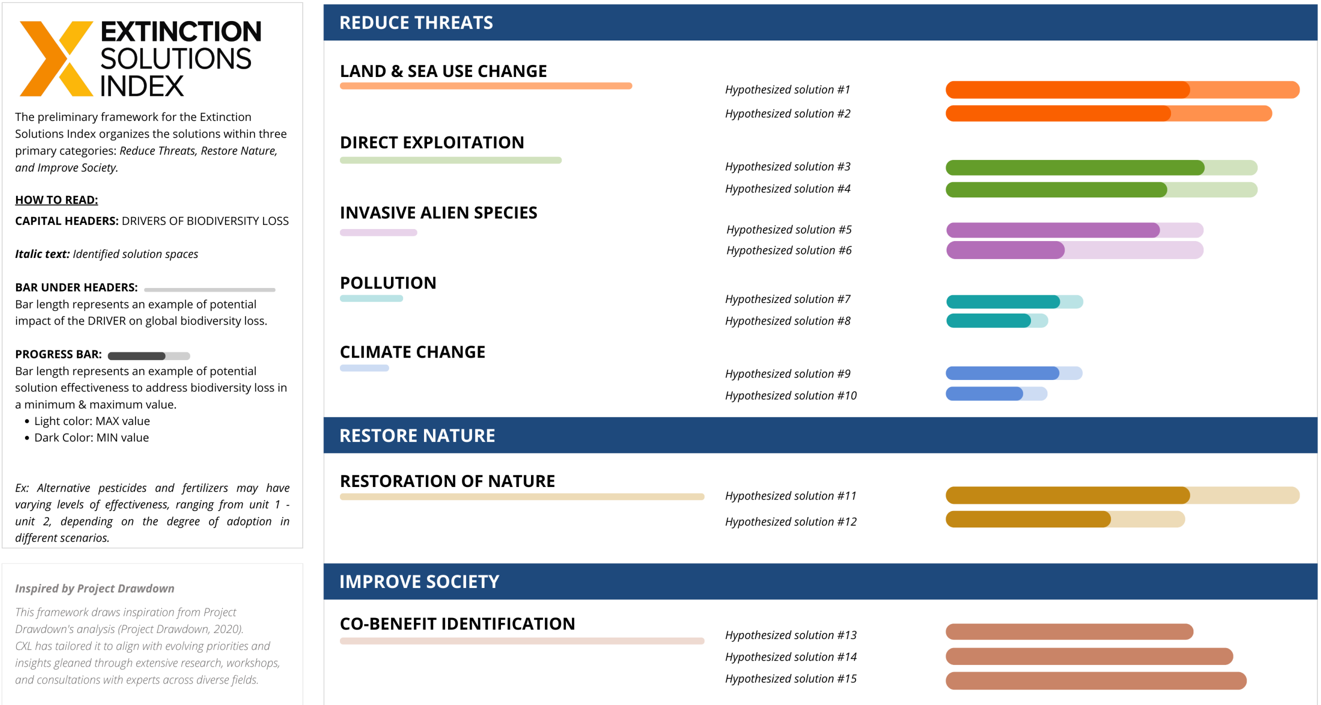

FIGURE 1 Inspired by Project Drawdown's original categorization (Project Drawdown, 2020) of climate solutions, the Extinction Solutions Index framework captures solutions that (1) reduce threats to biodiversity and take pressures off ecosystems by addressing land/sea use change, direct exploitation, invasive alien species, pollution and climate change; (2) restore composition and functions of ecosystems; and (3) incorporate socioeconomic interventions that result in improved conservation outcomes or have a material impact on the drivers of biodiversity loss. Under the main header of 'Reduce Threats', are the five global drivers of biodiversity loss in line with IPBES, with bars representing the proportion of global relative impact of threats via the Living Planet Index (IPBES, 2019; Purvis et al., 2019). Under the Restore Nature and Improve Society headers, are areas where mitigation activities or activities with many co-benefits can be categorized, respectively. The progress bars would (once evaluated) represent the potential impact of the solution on biodiversity loss through a minimum and maximum estimation based on adoption scenarios.

of harm), (2) restore composition and functions of ecosystems and (3) incorporate socioeconomic interventions that result in improved conservation outcomes or have a material impact on the drivers of biodiversity loss. The solution outcomes will have a minimum and maximum value, either through two projected market-driven adoption pathways for solutions or to measure extinctions avoided (minimum values, e.g. IUCN Red List Index) to potential recovery (maximum values, e.g. IUCN Green Status of Species) using different metrics (Akçakaya et al., 2018; IUCN, 2022). In this first iteration, we have organized solutions around the five global drivers of biodiversity loss—land/sea use change, direct exploitation, invasive alien species, pollution and climate change (IPBES, 2019). Recognizing the need to connect biodiversity solutions to economic sectors, we are also exploring organizing the solutions around agriculture, mining, healthcare, shipping and transport, energy production, infrastructure and consumer goods, while linking them to the drivers of biodiversity loss and the threats species face.

We are currently developing a full repository of solutions—which we define as a technology or practice that materially affects threats and drivers of biodiversity loss, restores nature or catalyses societal changes that lead to reduced drivers or enhanced restoration with specific and measurable outcomes inspired by Project Drawdown and One Earth articulations. These solutions will link directly to the drivers of extinction and to sectors of our economic activities, differing them from more traditional conservation action schemes. Our goal is to encourage investment into areas with the greatest potential for impact and into potential solutions that have yet to be created. Some hypothesized solutions across each of the three framework areas are provided in Table 1, highlighting the drivers of extinction, connection to economic activity and the core problem the solution addresses.

These solutions must be cost-effective to implement compared to their conventional counterparts taking into account market demand, be adaptable across different geographical locations and be designed with users in mind to facilitate transformative change (Dehgan & Hoffman, 2017). By initially identifying these ideas and constraints, we can allocate resources to enhance the competitiveness of these solutions. Future solutions can be inspired by the gaps identified in this analysis and could leverage innovative methods such as crowdsourcing to generate new ideas or improve existing ones to unlock scalability.

Upon gathering these solutions, we will need to determine any documented or hypothesized measures of their effectiveness. Ideally, we will automate this process using web scraping and Natural Language Processing to identify traditional solutions in academic literature and promising innovations articulated in patents, grant reports or whitepapers. These potentially disparate indicators

TABLE 1 Using the three categories of the initial Extinction Solutions Index (Reduce Threats, Restore Nature and Improve Society), a selection of hypothesized solutions are highlighted.

	Driver addressed	Associated economic sector	Problem to address	Hypothesized solutions
Reduce threats	Land/sea use change	Agriculture & Aquaculture	Food waste	• Genetically engineered crops • Controlled environmental agriculture • Utilizing 'imperfect' foods
	Direct exploitation	Retail & Consumer Goods	Demand for luxury goods	• Fur alternatives • Plant-based leathers • Biometric tracking
	Invasive alien species	Shipping & Transport	Contamination	• Ballast water treatment systems • Antifouling coatings • AI-enabled surveillance systems
	Pollution	Mining	Mercury	• Magnetized sluice boxes • Specialized sorbets replacements
	Climate change	Electricity	Fossil-fuel based energy	• Onshore wind turbines • Utility-scale solar photovoltaics • Distributed solar photovoltaics
Restore nature	Pollution	Chemical Agriculture (Pesticides, Fertilizers)	Ocean acidification	• Fertilizer with restoring by-products • Pesticide-free farming practices • Microbial farming practices
	Land/sea use change	Infrastructure Development (e.g., Roads, Urbanization)	Habitat reduction & fragmentation	• Wildlife crossings • Urban green spaces
Improve society	Direct exploitation	Healthcare	Human-wildlife zoonotic spillover	• One Health approach practices • Low-cost disease surveillance • Alternative proteins
	Land/sea use change	Agriculture & Aquaculture	Food security	• Integrated multi-trophic aquaculture • Crop diversification • Post-harvest storage technologies

Note: Each solution is associated with a main driver of extinction, a sector of the economy and a specific piece of that problem landscape the solution addresses. Users would be able to identify and prioritize solutions based on overall impact, economic sector, driver or problem area.

of effectiveness will then need to map to a change across selected biodiversity metrics useful for decision-makers and be compared to a baseline (e.g. counterfactuals or the conventional solution being replaced). We are currently in the process of building the solution repository via a survey of experts and desk research and will begin organizing these into the high-level framework to develop our evaluation and comparison methodology.

For the ESI's continued development, several challenges remain in the metric integration, scope determination and causality assessment. We intentionally emphasize biodiversity *loss* and solutions to the causes of *extinction*—as the name suggests—rather than other measurements of biodiversity impact, to help focus the analysis. Even when analysing multiple metrics to integrate, gaps exist between corporate disclosure frameworks and global biodiversity goals (The Taskforce on Nature-related Financial Disclosures, 2024; Zhu et al., 2024). For the ESI to be successful, integration across users and data types will be essential, and allowing for a comparison between these indicators may be the most powerful output option. The ESI aims for global applicability despite conservation traditionally being localized, requiring us to link actions potentially far upstream of the direct changes to biodiversity. Evaluating and isolating these solution impacts and causal relationships remains a challenge. Impact evaluation in conservation has been slow to mature, unlike sectors such as public health and education (Banerjee & Duflo, 2009; Baylis et al., 2016; Ferraro & Pattanayak, 2006), but this is beginning to change (Langhammer et al., 2024). The ESI will need to create bounds around a solution to consider causality, proximity, and confounding factors of the solution to address the drivers of extinction and be explicit in how these changes result in a change in state for biodiversity.

5 | DISCUSSION

Conservation science was born as both a crisis-based discipline, as well as a solutions-based discipline (Soulé, 1986), and now is a critical moment in history when conservation science can provide us with the answers to some of our most pressing environmental challenges. We know that conservation can succeed, but these efforts need to be scaled in the right places with adequate resources across all sectors of society (Langhammer et al., 2024). Market-based interventions hold promise for achieving the transformative change necessary to meet global conservation goals. Solutions need not be confined to the conservation discipline alone; solutions can—and must—come from anywhere or anyone to unlock our collective intelligence and prevent the sixth mass extinction. Substantial contributions to the ESI are sought from sector-specific experts in agriculture, manufacturing, transportation, finance, behavioural science, mining, consumer products and health, aiding in solution provision and understanding implementation requirements and data availability globally. By melding conservation's commitment to science-based discovery with innovative problem-solving and industry leadership, we can propel the field forward with bold, impactful action.

Armed with impactful solutions and a powerful decision-making tool for prioritizing resources, we can collaborate directly with philanthropies, governments, startups, investors, academia, non-profits and individuals to scale up adoption of solutions crucial for meeting global and local biodiversity goals. Having the list is just the beginning; ensuring the widespread adoption and implementation of solutions is a lasting call to change the way we create new economies. In areas lacking proper incentives or technologies, we can leverage these gaps to drive innovation toward sustainable products and practices that meet growing demands.

As global goals loom on the horizon in 2030 and 2050, we require an all-of-society effort toward creating a sustainable and habitable planet. Merely documenting species decline and implementing tried-and-true solutions for biodiversity conservation is no longer sufficient. We must cast a wider net to address the root causes of extinction. Luckily, we are seeing a shift toward this effort through disclosure frameworks like the Task Force for Nature-related Financial Disclosures, initiatives promoting nature-positive efforts, the advancement of new bioeconomies, and increasing movements toward net gains in biodiversity. However, for these initiatives to succeed, we must move beyond disclosures to prioritize and mobilize resources and tangible investments crucial for achieving a nature-positive planet. Without a solutions-focused tool, conservation will continue to look backwards and fall short of targets and goals for future generations.

The future of conservation depends on identifying and scaling successful actions, particularly those addressing the largest drivers of extinction with the greatest leverage and establishing conservation as a solutions-based discipline. The ESI provides a necessary framework for the future of conservation, encouraging us to reimagine, rebuild and reinvest in the most impactful solutions to prevent the loss of our planet's biodiversity.

AUTHOR CONTRIBUTIONS

Rachel N. Martin, Paul M. E. Bunje and Alex O. Dehgan developed the ideas in this perspective. Alex O. Dehgan and Paul M. E. Bunje are credited with the original idea and concept. Rachel N. Martin drafted and has summarized the research landscape, with substantial contributions from all co-authors.

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The authors declare no conflict of interest.

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The manuscript contains no original data.

ETHICS STATEMENT

The manuscript contains no content for which ethics approval was necessary.

ORCID

Rachel N. Martin https://orcid.org/0000-0001-5914-2132

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1: A selection of metrics, tools, and frameworks with their overview and measurement features that aim to capture various measures of biodiversity.

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