

Reimagining Training for the Next Generation of Ecologists

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ABSTRACT

Rampant environmental degradation and biodiversity loss underscore an urgent need for ecological knowledge that can directly help address social-environmental challenges. We argue that improved Earth stewardship needs ecologists to integrate foundational ecological knowledge to contextual understanding, relational practices, and engagement with decision-making when proposing effective solutions. Unfortunately, current training models prioritize other skills, such as quantitative analyses. This new emphasis is needed for ecologists, as these aspects may shape the questions ecologists ask, the actors they engage with, and the roles they play across the science–policy–practice interface. Building on existing discussions of translational ecology, decision science, intra-, inter- and transdisciplinary collaboration, and the ethics of care, we highlight three priorities for reimagining ecological education: developing interdisciplinary and transdisciplinary knowledge; fostering inclusive participation; and orienting ecological training toward transformative societal impact. We translate these priorities into three interconnected educational pillars and illustrate their application through existing programs. By centering values, inclusivity, and real-world engagement in ecological training, we can equip future ecologists with the skills, commitments, and sense of responsibility needed to contribute to more just and sustainable futures by addressing social-environmental challenges.

Keywords: decision science, ecological education, science-policy-practice interface, transformative learning, translational ecology, value-driven training

Human modification of natural ecosystems and concomitant species extinctions are occurring at an alarming pace (Johnson et al., 2017). Major threats to biodiversity include habitat loss, degradation due to biological invasions, climate change, land-use change, overexploitation of natural resources, and pollution (IPBES et al., 2019; Jaureguiberry et al., 2022). Ecological research has generated major insights after a century of advances in understanding the threats and responses of ecological systems to these drivers at multiple scales (Haubrock et al., 2025; Staudinger et al., 2013). However, the translation of these insights into solutions that address

social-environmental challenges remains limited (Buxton et al., 2021). What stands in the way of turning ecological knowledge into meaningful change or action?

We argue that this obstacle is in part due to how ecologists are trained. We do not posit that environmental crises arise from educational shortcomings, nor that changing how ecologists are trained would be sufficient to counterbalance systemic issues such as harmful policies, extractive economic models, or power imbalances. Rather, we believe reimagining training to include a broader suite of skills might be one of many leverage points to contribute to the social, political, and institutional change required to safeguard biodiversity going forward. How ecologists are trained ultimately shapes the questions we ask, the actors we engage with, the roles we play, and how impactful we become.

The field of ecology increasingly values and relies on quantitative methods. As a result, current educational paradigms emphasize quantitative skills training (Cooke et al., 2021; Klug et al., 2017). This trend may be attributed to the inherent difficulty of ecological science, which has historically necessitated strong emphasis on rigor, theory, and methodological discipline (R. Cousens, 2023), but also to recent institutional incentives that favor scalable and cost-efficient training models. At the same time, many applied ecology and conservation training programs have become increasingly oriented toward marketable technical skills (such as GIS, environmental impact assessments, radiotelemetry, forecasting, and machine learning). Focus on quantitative and other technical tools often comes at the expense of skills related to contextual understanding, reflexivity, and engagement with decision-making. This growing emphasis on quantitative approaches in ecology has sometimes displaced the integration of natural history and lived experience in nature (Nanglu et al., 2023; Soga & Gaston, 2025), which play critical roles in shaping the awareness and actions that drive effective responses to global social-environmental challenges (Soga & Gaston, 2024).

Although the increasingly sophisticated outputs of artificial intelligence (AI) and ecological statistical tools generate valuable insights, their application in real-world contexts often falls short of addressing the practical needs of decision-makers and communities when problems are insufficiently defined or contextualized. As long argued in environmental education, the problem is not lack of knowledge, but the way that knowledge is conceived as detached from responsibility, context, and consequences (Orr, 2011). In parallel, Morozov (2014) warned that prioritizing technical fixes over social reflection risks reinforcing inequities in whose knowledge and priorities count. These themes are central to many broader theories and models of transformative change (Pahl-Wostl et al., 2023) and they have received increasing attention in the interdisciplinary research community (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services et al., 2022). However, the discussion on how to transform the training of ecologists has been limited.

A key challenge is building skills in problem framing and collaboration alongside core ecological concepts and quantitative expertise, as the emerging subfield of Translational Ecology increasingly addresses (Enquist et al., 2017; Schwartz et al., 2017). Ecologists are rarely trained to define problems in ways that directly connect evidence with real decisions; the integration of

principles from decision science (e.g., problem framing, evaluating trade-offs; Hemming et al., 2022), as well as prioritizing co-design or co-production of solutions with non-academics (Kurlle et al., 2022), for example, can help fill this gap. Such approaches emphasize the context dependence of decision-making, particularly when ecological theories and methods are applied to local realities that are different from those in which they were developed. A context-aware mindset can help ecologists-in-training to develop a more integrated perspective of how people perceive and act upon risk, as well as the priorities and trade-offs that manifest in real-world situations. Such a context-aware mindset would allow research to directly inform decision making.

Here, we posit that translating research into effective solutions requires a collaborative and co-designed process in which research is co-designed to directly support decision-making, rather than the transfer and ‘translation’ of results into local applications, *i.e.*, knowledge transfer models in which knowledge is produced first and applied later. This process requires training for inter- and trans-disciplinary collaboration, stakeholder and cross-cultural engagement, and skills in communication, facilitation, deliberation, negotiation, and policy-making. However, ecologists often lack this broad training, which would allow them to work effectively at the science-policy-practice interface with culturally diverse forms of knowledge, groups of scientists, decision makers, and practitioners, to co-construct strategies contextualized to the places where research and management occur. Deeper appreciation of relational and place-based ways of understanding nature, such as Indigenous Knowledges (Tassell-Matamua, 2025), and stewardship of nature are crucial for future ecologists, both in framing meaningful research questions and in applied roles such as managers, practitioners, and policy-makers.

Finally, researchers, educators, and practitioners working in the fields of ecology and conservation biology often operate on the presumption of a set of values and ethics essential for tackling current social-environmental challenges, yet these are not always explicit nor fully shared across ecological and conservation endeavors (Arnillas et al., 2026; Cardou & Vellend, 2023). This lack of explicitness about values and motivations contributes to a broader disconnect between how ecologists are trained and how they perceive their societal roles, including the ethical responsibilities and accountabilities associated with the knowledge they produce and publish. In part, these gaps stem from the lack of training in an *ethos* of care—an ethical orientation that, in fields such as nursing and social work, is explicitly embedded in professional training of core competencies such as empathy, accountability, and responsibility (Parsons & MacCartney, 2025). In ecology, these relational dimensions are rarely implemented or discussed in scientific training. Therefore, we advocate for a more purposeful reflection on, and articulation of, the values that underpin ecologists' motivations and expectations in institutions of higher education and other training environments.

To meet the urgency of addressing the current ecological challenges, we propose a transformative shift in how ecologists are educated—one that prioritizes critical reflection on individual and collective professional values, a commitment to inclusivity and diversity within the ecological workforce, and an explicit orientation toward societal impact. It is critical to create

an educational ecosystem that equips ecologists with the tools to effect meaningful change to address ecological challenges. This requires more than technical training in advanced statistical skills, instruction on the foundations and principles of ecology, and rigorous experimental design or laboratory skills (all of which are important!); it demands a paradigm shift toward understanding our roles and responsibilities in society as ecologists, fostering meaningful engagement with diverse actors, and a realignment of research objectives to focus on societal and environmental impact. These issues demand ecological knowledge that engages holistic approaches to understanding the pathways leading to environmental change and sustainability in the long run (Tilman, 2022).

Shifting the training paradigm for the next generation of ecologists

Importantly, the role of ecologists is not fixed; it has evolved and it is still evolving in response to changing social-environmental challenges, societal expectations, and technological and disciplinary advances (Cousens & Dale, 2023). Over the past fifty years, ecologists were often trained primarily as basic scientists focused on describing natural systems and processes. Today, ecologists are generating knowledge, but they also address environmental crises, communicate findings to broader audiences, and contribute to policy and social transformation (Weyland & Von Below, 2021), including through science communication, policy engagement, and assessments (Geschke et al., 2023). Much of this increasing engagement is driven by prosocial motivations of academics who feel a responsibility to act, communicate, and collaborate in ways they believe can contribute to society (Atta-Owusu & Fitjar, 2022; Püttmann et al., 2023). While the scope of these responsibilities has expanded, training pathways and institutional expectations within academic systems—such as universities, hiring, and evaluation frameworks—often remain narrow, privileging technical proficiency and publication output over broader forms of engagement and impact (Cano-Barbacid et al., 2025).

A transformative shift in training must therefore recognize this evolving landscape not because institutions demand it, but because contemporary environmental crises do. Although many universities and funding agencies explicitly support research addressing societal priorities, a persistent gap remains between ecological knowledge and the decision-making and governance systems needed to tackle environmental crises. Therefore, ecologists should be trained to connect scientific skills with societal action in order to navigate this reality. Although the specific content and depth of training will differ across undergraduate, graduate, and professional pathways, the priorities we outline here are applicable across stages of ecological education, and can be implemented both through the restructuring of existing courses or as complementary training components. We draw from the principles of transformative learning (Singer-Brodowski, 2023) and propose that the training of ecologists be guided by three main priorities (Figure 1):

- **Interdisciplinary and Transdisciplinary Knowledge:** Students should be exposed to experiential learning in nature and learn to navigate and integrate insights from other systems that shape environmental outcomes, including social, cultural, legal, and economic dimensions (Markauskaite et al., 2024). Calls for

inter- and trans-disciplinarity are no longer sufficient; what is needed are learning opportunities where diverse epistemologies are brought into dialogue, allowing students to engage with different ways of knowing to foster mutual understanding and create new, emergent knowledge (Morgan et al., 2025). In practice, this means preparing students to work with knowledge generated beyond academia, including Indigenous and local knowledge systems, management expertise, and policy-relevant insights in addition to an awareness of diverse academic disciplines (Kurle et al., 2022). Incorporating Indigenous and traditional perspectives alongside scientific approaches expands the epistemic foundations of ecology and strengthens the capacity to engage with culturally diverse knowledge holders, stakeholders, worldviews, and knowledge systems (Zidny & Eilks, 2020). Broadening the knowledge pillars for future ecologists would foster ethical and scientific grounding in the social sciences and in-depth reflections on their societal roles. Thus, inclusive and place-based ecological knowledge might support value-driven decision making, both in students' professional roles and in how they choose to engage with social-environmental challenges in everyday life.

- **Inclusive Participation:** Equity, diversity, and inclusion should shape how ecological training is organized and practiced, ensuring that ecologists are trained in the principles and practices of meaningful, respectful engagement with Indigenous Peoples and with local and marginalized communities, whose long histories of collective action, stewardship, and resistance can offer critical lessons to enact societal change (Jennings et al., 2025). Inclusive participation focuses not on what knowledge is used, but on who is involved, how decisions are made, and how power, responsibilities, and benefits are shared throughout research and practice. Effective ecological education must create opportunities for students to develop skills to form and foster partnerships with relevant local communities, land managers, Indigenous groups, policymakers, government, and NGOs, each one bringing distinct perspectives, interests, and motivations (Vance-Chalcraft & Jelks, 2023). Encouraging these exchanges helps students learn to navigate across cultures, values, and disciplinary boundaries. Such experiences would prepare future ecologists to develop research and practice programs that are better designed to address diverse societal needs across multiple spheres of action. Ensuring diverse participation also requires a genuine transformation of how ecology is taught and practiced by broadening who participates across career stages, institutional roles, and decision-making positions, and how knowledge is co-created and valued (Byrne et al., 2025).
- **Transformative Impact:** The ultimate goal of ecological education is to prepare ecologists to become changemakers, who can combine technical expertise with the ethical grounding, critical thinking, and relational awareness needed to address social-environmental challenges. Achieving this requires cultivating not

only new methods but also ecological research and practice that bridge theory and application, and consider uncertainty, context, and scale. Training should emphasize critical solution-oriented inquiry, community engagement, and stewardship that connects ecological knowledge with decision-making processes across science, policy, and society, preparing ecologists to shape decisions and governance pathways that foster more just and sustainable futures. This includes promoting a decision-science mindset that supports ecologists to frame questions and clearly communicate uncertainty in ways that inform governance and action (Adams et al., 2023; Hemming et al., 2022).

These priorities should not be understood to be a single training program across all stages of education, but instead guide their application to the specificities of each training level. For example, undergraduate training may emphasize ecological concepts, exposure, values formation, and experiential learning that connects ecological concepts to real-world contexts. Master's and professional programs may prioritize applied skills, collaboration with practitioners, and decision-relevant research. Doctoral training can deepen theoretical and methodological expertise while cultivating leadership, mentoring, and engagement at the science-policy-practice interface. Postdoctoral training can provide opportunities for development of facilitation and deliberation skills. Across these different pathways and educational levels, the unifying goal is to prepare ecologists to responsibly connect their growing knowledge with action.

Across all three priorities, ecological training must also encompass foundational training in the social sciences. Concepts from sociology, anthropology, psychology, and political science help ecologists recognize how power relations, cultural worldviews, governance structures, and historical contexts shape environmental outcomes and mediate interactions among actors. This training can improve the skills to engage with people that have different relationships with nature, thus strengthening the ability of ecologists to work across knowledge systems and to co-design solutions that are responsive to diverse social-ecological realities. Strong theoretical and empirical ecological knowledge, as well as quantitative skills, remains essential for the discipline, but the societal relevance of their application depends on ecologists' capacity to understand social context and purpose. Foundational knowledge in the social sciences ensures that ecological knowledge is interpreted and responsibly applied in ways that are responsive to complex real-world scenarios.

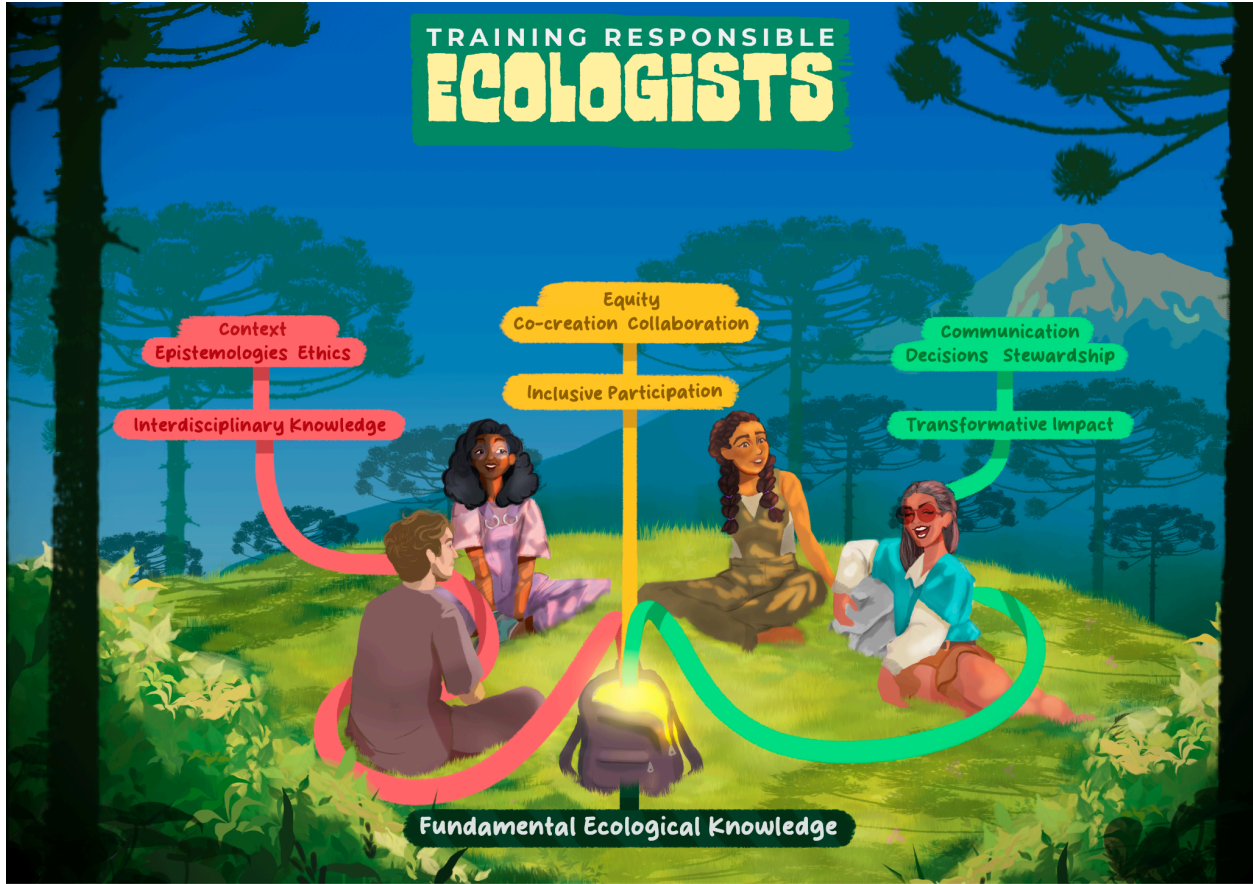


Figure 1 - Illustration depicting an integrated model for a reimagined ecological training grounded in fundamental ecological knowledge but structured around interdisciplinary knowledge, inclusive participation, and transformative societal impact. Foundational ecological knowledge underpins all components, supporting the contextualization of ecological research within ethical, social, and decision-making processes. Illustration by Danilo Ricardo.

Implementing this vision requires a collaborative effort across academic disciplines and professional fields. A core component of this effort would be re-designing ecology and post-graduate curricula across various universities in both the Global North and South, and concretely defining how the desired skills are embedded in them. Either through redesigning current courses or through parallel opportunities such as workshops, group projects, and community engagement activities should be central, allowing learners to develop transferable skills and apply their knowledge in real-world contexts.

The SEEDS program of the Ecological Society of America provides an inspiring model particularly aligned with the Inclusive Participation priority, centering mentorship, field work experiences, and leadership development to support students from underrepresented backgrounds in ecology. This program is focused on advancing a more inclusive ecological workforce through cohort-based activities that strengthen a sense of identity, belonging, and retention (Ahern-Dodson et al., 2020). Another pertinent example is the Living Data Project, a Canadian program that trains students in data management and scientific collaboration by connecting participants with diverse stakeholders who hold valuable but at-risk biodiversity datasets, thus providing an opportunity for training and rescuing data (Bledsoe et al., 2022). Initiatives such as the ANdiNA VI Workshop—an immersive program that brought together an interdisciplinary team—further demonstrate how training and mutual exchange can cultivate care, inter-epistemic dialogue, and place-based commitment (Yannelli et al., 2025). Transdisciplinary training programs such as the Smith Fellows program offered in partnership with the Society for Conservation Biology, the IPBES Fellowship Programme and courses and degree programmes offered by the Stockholm Resilience Centre, similarly highlight how collaboration across scientific, policy, and community spheres can be cultivated. Together, these initiatives demonstrate that collaborative and practice-oriented training is both feasible and effective.

Building transformative teaching curricula

As a first step toward redesigning ecological training, we propose a flexible curriculum framework that can complement existing undergraduate and graduate programs, serve as the backbone for specialized certificates or professional diplomas, or even inspire adaptations through traditional courses. The intent is to create a model that can be adapted to different stages of ecological education centered around five core pillars aimed at fostering engaged professionals with diverse societal roles. Building on the three priorities outlined above (Interdisciplinary Knowledge, Inclusive Participation, and Transformative Impact), we translate these principles into five interconnected pillars of ecological education that can be adapted into specific courses or embedded in current training (Table 1). Each pillar is designed to integrate ethical reflection, inclusivity, and real-world engagement into ecological training.

Table 1 - Five interconnected pillars aligned with the three proposed overarching priorities for reimagining ecological training. These pillars should be considered complementary to the core disciplinary training in ecology by strengthening capacities related to participation, decision-making, ethics, and societal impact.

Pillar	Aligned Priorities	Core Focus	Key Learning Outcomes and Skills
What are ecologists for?	Transformative impact	Reflection on values, ethics, and societal roles and responsibilities of ecologists	Ethical reasoning; articulation of personal and collective values; care-centered reflection on societal responsibilities; awareness of diverse career pathways (research, policy, practice, educator, communication, advocacy)
Approaches to ecology from the ground up	Interdisciplinary & transdisciplinary knowledge; inclusive participation	Place-based, experiential ecological research co-developed with culturally diverse actors	Field-based learning; integration of multiple knowledge systems; engagement with local, Indigenous, and practitioner perspectives; contextualized problem framing
Interfacing with policy and decision science	Transformative impact	Connecting ecological research to real-world decisions	Application of decision-science principles: problem definition; articulating objectives; identifying alternative; evaluating trade-offs; communicating uncertainty; and policy literacy
Connecting with communities	Inclusive participation	Engagement, communication, and knowledge co-creation with broad audiences	Science communication; participatory and community science design; outreach strategies; relationship-building with communities and stakeholders
Collaboration practice in ecology	Inclusive participation; Interdisciplinary & transdisciplinary	Working effectively in teams across disciplines and sectors	Leadership; mentoring; team management; negotiation; interdisciplinary collaboration; skills for collective action and institutional change

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Across all five pillars, experiential training should be central in preparing ecologists for a socially engaged and impactful career. Co-designed opportunities with key partners in multiple spheres, such as NGOs, societies of land managers, professional societies, government agencies, Indigenous organizations, and museums, can center around real-world deliverables: data support and archiving, systematic reviews on priority topics, or tools to inform the effectiveness of, or priorities for, local actions, such as local-scale land management plans. Connecting students to communication projects or social movements can equip them with skills to carry out science communication or participatory research, while group reflection spaces (*e.g.*, facilitated storytelling, journaling clubs) can support values-driven orientation (Pandya et al., 2025). These activities need to be strategic and co-designed with partners to generate actionable outcomes, such as white papers, policy briefs, or management plans, thus building synthesis and knowledge mobilization skills. Sowing long-term, place-based alliances instead of short-term, transactional engagements can help cultivate a sense of commitment, responsibility, and attachment to social-environmental contexts where research and action occur. When integrated into a curriculum developed around our three priorities, these activities would support ethical collaboration and the ability to translate ecological knowledge into action across academic, governmental, non-governmental, and community-based roles, even when such commitments are not aligned with prevailing professional incentives. At the same time, they require sustained engagement and capacity from all partners involved.

This reimagined training ecosystem integrates insights from ecology and education to reshape ecological training for real-world impact. We highlight the need to engage locally, think critically, and act collectively. These principles are supported through the three priorities listed herein. This call emerges from the vision of an education oriented toward social transformation (Freire, 2005) and rooted in best practices and the lived experiences of learners in a way that promotes local action and cultivates a sense of hope, empowerment, and agency that can effectively transform trainees' attitudes toward sustainability (Leichenko et al., 2022).

As ecologists our collective actions must reflect our values, address societal needs, and contribute to a more sustainable society. However, centering the pedagogical training of ecologists is crucial to working towards goals of impactful solutions. There is a rapidly shrinking window of opportunity to revolutionize ecological training if we intend to meet such goals. By centering values, inclusivity, and real-world engagement with people and nature in our educational practices, we can empower the next generation to lead the way toward a sustainable future.

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