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Extinction of experience among ecologists

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Fieldwork-based research and education in ecology are under multiple threats and are progressively declining. We call for greater attention to this ongoing loss of direct field experience within the ecology community, as it could have widespread consequences for science and education, ultimately hindering efforts to address the ongoing biodiversity crisis.

Widespread decline in fieldwork-based research and education

Many human populations are experiencing a progressive decline in direct interactions with nature [1]. This loss, known as the **extinction of experience** (see Glossary), has attracted significant attention in applied ecology and conservation biology due to its adverse impacts on addressing the ongoing biodiversity crisis [1]. Indeed, individuals who do not engage directly with nature, or who do so in only a very limited fashion, are less likely to be interested in, supportive of, or involved with nature conservation and management policies and practices [1].

The extinction of experience, typically discussed in terms of reduced nature interactions among the general public, is also evident within the ecological community. There has been a progressive decline in fieldwork-based research and education in ecology over recent decades [2–4]. This decline in fieldwork has raised concerns within the ecology field and beyond [4], but such attention has been sporadic, and a systematic exploration is lacking. We provide a brief overview of the potential causes and consequences of the decline in fieldwork in ecology and outline key recommendations for future research.

Drivers

The ongoing decline in fieldwork in ecology is likely a consequence of a combination of factors that impact opportunities, motivation, and capability for conducting fieldwork [2,4] (Figure 1). These include diverse social, economic, environmental, technological, educational, and cultural influences, although their relative importance remains poorly understood due to limited quantitative studies. For example, opportunities for researchers and students to engage in fieldwork are increasingly restricted by limitations in funding, time constraints (including due to family or caregiving responsibilities) [5], societal pressures to reduce the **environmental footprint** of scientific activities [6], societal pressures to restrict **helicopter/parachute science**, the closure of field stations, the growing proportion of researchers and students affiliated with institutions located in urban areas, and technological advances in monitoring ecosystems, such as through unmanned aerial vehicles (UAVs), camera traps, acoustic loggers, and environmental DNA (eDNA) [7]. Additionally, motivation is likely eroded by unpredictable weather and political or socioeconomic instability, complicating fieldwork planning [8]; heightened societal focus on health and safety [9] and work/life balance (i.e., increased priorities for personal activities); increased acknowledgment of risks faced by researchers and students from minority backgrounds [10]; greater academic awareness of conducting research using large environmental and ecological datasets and synthesising existing evidence (e.g., meta-analysis) [11]; and the rising pressure on researchers to publish work for their careers to succeed (some fieldwork-based studies – especially those that involve frequent or remote activities – can be time-consuming and costly). Furthermore, the decreased emphasis on natural history in school curricula [12] is likely diminishing young people's interest in nature and limiting their ecological knowledge, both of which are crucial for building the motivation and capability needed for fieldwork activities.

These factors are often interrelated. For example, heightened health and safety requirements can increase fieldwork costs by necessitating additional training, larger teams, or specialised equipment. Also, importantly, the influence of different factors on fieldwork varies across countries and among different groups or sectors, depending on their socioeconomic, environmental, and cultural contexts.

Consequences: both positive and negative

Some of the aforementioned driving factors have positive implications. For instance, limiting long-distance transport for remote fieldwork lowers carbon emissions [6]. Advances in ecosystem monitoring technology have also enabled the rapid, non-invasive collection of high-resolution, multi-dimensional data, revolutionising many subdisciplines within ecology [7]. These technologies have also made certain types of fieldwork less physically demanding and more accessible to individuals with diverse lifestyles or responsibilities, thus lowering barriers to entry for some groups. Similarly, increased awareness of

Glossary

Eco-literacy: the ability to understand the ecosystems that sustain life on Earth and to develop the skills necessary for environmental stewardship.
Environmental footprint: an environmental indicator that measures the amount of natural resources consumed by an individual, an organisation, or a country, relative to the Earth's capacity to regenerate those resources.
Extinction of experience: the progressive loss of direct human interactions with nature.
Helicopter/parachute science: a practice where researchers from high-income countries conduct studies in low-income countries with little or no engagement from local researchers or communities.
Personalised ecology: the set of direct sensory interactions that an individual person has with nature.

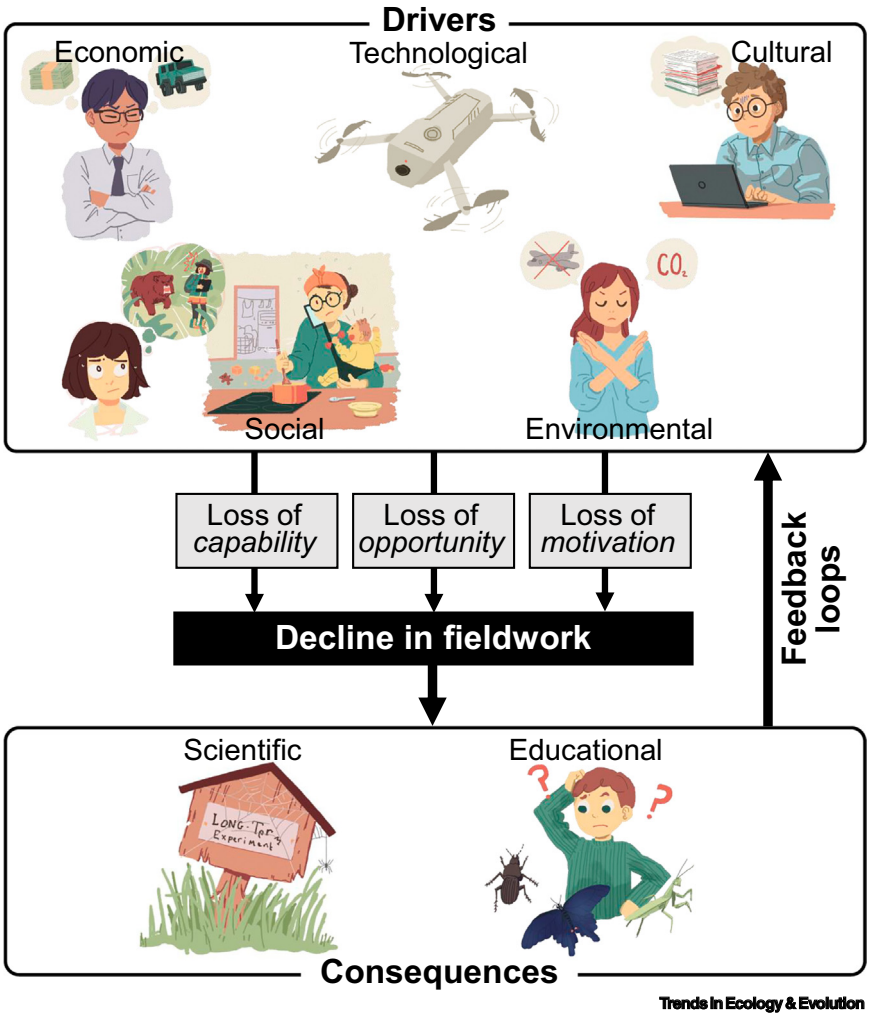

Figure 1. A conceptual framework for understanding the causes and consequences of decreased fieldwork-based ecology research and education. Various social (e.g., societal expectations, regulations), economic (e.g., limited funding, rising research costs), environmental (e.g., ecological degradation, climate change), technological (e.g., use of remote sensing over field observation), educational (e.g., declining focus on natural sciences in school curricula), and cultural (e.g., shifting academic values regarding fieldwork-based studies) factors can reduce the capability, opportunity, and motivation to conduct fieldwork-based research and education. Decreased fieldwork can negatively impact ecological research and education, which in turn can hamper efforts to address the ongoing global biodiversity decline. Several feedback loops likely exist, where declines in fieldwork lead to further reductions in these activities.

health and safety issues in fieldwork, along with a greater emphasis on work/life balance, can support historically marginalised and minority groups in entering and remaining in the field of ecology, fostering greater diversity and inclusion [9].

However, the decline in fieldwork can also have negative consequences for multiple aspects of science and education in ecology (Figure 1). From a scientific perspective, fieldwork plays a critical role in almost every stage of the scientific process, from initial idea generation and hypothesis formulation (which have historically been heavily driven by in-person field observations) to data collection and synthesis [13] (Table 1). Thus, a decline in fieldwork could hinder scientific progress in some areas of ecology, especially those that rely heavily on direct wildlife observation, such as behavioural ecology, species inventories, and biodiversity monitoring [11]. For example, what was once thought to be a large-scale extinction of plant species in tropical cloud forests – the so-called 'Centinelan extinction' – was later found to be a result of insufficient survey efforts, as recent field investigations have refuted the hypothesis [14]. Additionally, reduced fieldwork may limit ecologists' engagement with local communities (including local scientists), thus reducing the incorporation of traditional or local ecological knowledge, increasingly acknowledged as essential for effective ecosystem and natural resource management.

Similar to its impacts on scientific activities, decreased fieldwork could diminish several key outcomes of ecology education, including knowledge acquisition (e.g., understanding natural history of wild plants and animals), skills acquisition (e.g., species identification ability), attitudinal change (e.g., fostering environmental stewardship), and habit change (e.g., adopting environmentally friendly practices). Fieldwork-based activities provide students with direct experiences of wild organisms and ecosystems, enriching their **personalised ecologies** [1]. These experiences can foster a deeper interest in and understanding of nature (**eco-literacy**) and help strengthen environmental stewardship among young people who will shape future policies and actions [1]. For example, educational activities involving fieldwork have been shown to be an effective means of teaching about biodiversity [15].

The impacts of declining fieldwork on science and education may take decades fully to manifest, making them difficult to measure. Nevertheless, it is crucial to begin proactively considering steps to mitigate these impacts, rather than waiting for the consequences to become apparent. Addressing

Table 1. Examples of the negative impacts of the decline in fieldwork-based research and education in ecology on scientific and educational outcomes. Scientific outcomes are grouped according to the major stages of the scientific process, while educational outcomes are categorised by the major learning aspects

Category		Factor
Scientific	Experience	• Reduced opportunities to acquire field-related knowledge and skills • Fewer chances to engage with local communities and local stakeholders
	Initial idea creation	• Reduced exposure to events that inspire research ideas
	Hypothesis formulation and testing	• Reduced scope for generating and testing new hypotheses • Increased likelihood of errors in hypothesis development and relevance
	Staff recruitment	• Decline in societal (e.g., student) interest in pursuing environmental careers
	Data collection	• Difficulties in maintaining long-term ecological monitoring and field experimental programmes
	Publication	• Decline in number of fieldwork-based studies being published, slowing the accumulation of new knowledge about ecosystems
	Synthesis	• Challenges in adequate field studies for evidence and data synthesis (e.g., meta-analyses)
Educational	Knowledge	• Decline in understanding of nature and environmental issues
	Attitudes	• Decline in beliefs and perceptions that support efforts for environmental protection
	Skills	• Decline in ability to assess and take action to protect wild organisms and natural environments
	Habits	• Decline in actions that support conservation efforts for environmental protection

this issue requires gathering the best possible evidence available at present and predicting potential major outcomes. While measuring these impacts through a longitudinal approach (i.e., tracking changes over time) may be difficult, a cross-sectional design can still offer valuable insights. For instance, a retrospective survey could examine the relationship between undergraduate fieldwork experiences and individuals' current career trajectories and researchers' adopted methodologies.

Feedback loops

The decline in fieldwork can create a self-reinforcing cycle, leading to further reductions in fieldwork activities by eroding capability, opportunity, and motivation (Figure 1). Although the extent to which these feedback loops are currently operating remains unknown, several plausible scenarios illustrate their potential impact. For example, as students have fewer fieldwork experiences, such as field trips, they may lose interest in studying wild organisms, diminishing their inclination to pursue careers in ecology as PhD students, technicians, and researchers, making it more challenging to develop the next generation of field researchers. Furthermore, declining fieldwork activities can weaken researchers' connections with local collaborators and practitioners, reducing their capacity to conduct effective field research.

Moving forward

Finally, we outline four key points that discussions on the decline of fieldwork in ecology will benefit from. First, these discussions should explore how to balance fieldwork with other essential research and educational activities rather than focusing solely on the importance of fieldwork. While fieldwork is crucial, non-fieldwork activities – such as modelling, data analysis, and evidence synthesis – are equally vital for advancing ecological knowledge. Given the limited time and resources available, it seems important to clarify, using empirical data, broadly how resources should be allocated to fieldwork-based research and education to maximise research impact and educational outcomes. Of course, optimal resource distribution will vary across fields and topics (and likely through time), highlighting the need for flexible guidelines.

Second, it is essential to explore how fieldwork and non-fieldwork activities can create synergistic outcomes. Although these approaches are often viewed as trade-offs [2,11], they are not mutually exclusive but rather can complement and enhance one another. For example, ecological insights gained through fieldwork can refine and improve the accuracy of species distribution models. Likewise, in educational settings, combining fieldwork with laboratory methods such as eDNA analysis can provide students with a richer understanding of ecosystem dynamics and environmental change. Identifying strategies to maximise these synergistic effects will be crucial for advancing both ecological research and education.

Third, it is important to explore how to balance the benefits and costs of fieldwork-based activities in terms of environmental sustainability. While fieldwork contributes to biodiversity conservation by providing scientific evidence and training individuals, it can also have negative environmental impacts, such as increased carbon and biodiversity footprints. Given the growing societal demands to reduce the environmental footprint of scientific activities [6], the ecology community needs more discussion on how to

mitigate negative effects and maximise the net gain in environmental health outcomes. One approach to addressing this issue is to reduce helicopter or parachute science by fostering local researchers' involvement in fieldwork within their own regions, thus lowering travel-related impacts and strengthening local expertise.

Fourth, considering the wide-ranging contributions of fieldwork-based research and education to ecology, it seems critically important to adapt academic and educational systems to ensure these activities endure in a rapidly changing world. Potential barriers to fieldwork could be addressed by enhancing public funding for field research facilities and infrastructure, implementing educational programmes or policies to mitigate health and safety issues outdoors [9], promoting natural history education in schools and universities [12], ensuring that field-based research is published in influential academic journals, and considering fieldwork experience in awards and hiring decisions [4] (see [4] for a detailed discussion on actions to remove barriers to fieldwork). Addressing these points will require broad collaboration across various sectors, involving researchers, educators, government agencies, local communities, and publishers.

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Declaration of interests

The authors declare no competing interests.

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