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Editorial: Long-term monitoring in ecology and evolution: establishing a sound baseline to help inform our future

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Editorial on the Research Topic
Long-term monitoring in ecology and evolution: establishing a sound baseline to help inform our future

Since the earliest days of research in ecology and evolution, organisms have been observed and tracked in their natural environments. Observations are a necessary first step in understanding biological processes, serving as an initial glimpse into natural phenomena such as species occupancy and abundance, associations between individuals and their environments, system responses to natural or anthropogenic disturbance, and processes underlying life history variation (Sagarin and Pauchard, 2010; Clutton-Brock and Sheldon, 2010). When extended through time, observational data form the basis of long-term monitoring, documenting changes in populations, species or systems over prolonged periods ranging from years to decades (Lindenmayer and Likens, 2018). Long-term monitoring has the potential to detect and explain complex temporal variation in ecological or evolutionary processes, and thus may be well-positioned to act as a cornerstone for tracking some of the big challenges currently facing environments and society. However, long-term monitoring is criticized for being too descriptive and not relying sufficiently on hypotheses and testable predictions, meaning that research results can be inconclusive or even spurious (Lovett et al., 2007). Long-term monitoring often lacks focus because relevant species or interactions are not tracked with the rigor or temporal variability needed for strong inference. It follows that much long-term monitoring may not be sufficiently nimble to address emerging or priority research topics, and targeted approaches like field experiments or before-after-control-impact studies can yield stronger findings in a more time- and resource-efficient manner. Thus, long-term monitoring may be less attractive to researchers seeking to maximize productivity or to funding agencies expecting conclusive findings through a typical 3-5 year grant cycle. Collectively, these concerns may cast doubt on the current and potential future importance of long-term monitoring in ecology.

While it is indisputable that long-term monitoring faces challenges of legitimacy and perceived relevance in today's research landscape, we feel that this investigative approach remains crucial for addressing a range of questions where patterns are only revealed through longer time periods and where extended observations are needed. This Research Topic highlights new tools and approaches showing that long-term monitoring remains a useful approach in contemporary ecology and, if properly designed and conducted, can play a critical role in understanding broader ecological and evolutionary dynamics.

A crucial development in contemporary long-term monitoring is the adoption of new technologies for robust data collection and analysis. Traditional methods for surveying cryptic aquatic amphibians are typically crude and invasive, but when combined with results from environmental DNA (eDNA) surveys, species detection rates can be improved substantially (Wikston et al.). This improvement can lead to better tools for tracking amphibian community composition and change. New technologies should receive appropriate validation before being fully integrated into monitoring programs, but such steps are often overlooked because they require ancillary data and testing. Henrich et al. showed that population density estimates derived from trail cameras are improved substantially when adjusted for potential bias from animal movements (as inferred from radio-telemetry), and that such estimates vary between ungulate species. Similarly, development of automated workflows can provide a valuable framework for improving both accuracy and efficiency of novel population survey methods, with machine learning and automation strengthening drone-based surveys of pinniped abundance and body size (Infantes et al.). An important challenge in designing comprehensive long-term monitoring programs is that sometimes different datasets must be combined while also accounting for their discrepancies and inconsistencies. Using a series of diffusion maps centered on species traits, Carrasco De La Cruz et al. were able to track functional diversity in phytoplankton communities using multiple, disparate datasets from different jurisdictions spanning a broad geographical region that otherwise could not be surveyed via singular counts.

Contemporary long-term monitoring programs often center around assessing the impact of ongoing environmental change on species abundance; such studies need an extended time series of observations to accurately record population trends and variation. Using a half-century of daily counts, de Eyto et al. reported seaward and upstream migration phenology of several Irish fish species, with some species showing modest changes versus others exhibiting dramatic variation related to declining trends in survival and body size. Krebs et al. showed through 50-year monitoring of plant and animal abundance in Canada's northern boreal forest, that some species experienced local extinctions or altered population fluctuations. Yet, the observed high numerical variability across sites in the study region indicates that broader ecosystem-level changes such as cyclic attenuation or predator community shifts remain inconclusive. Four decades of intensive vertebrate research in Canada's Arctic were necessary to infer a variety of findings related to predation's role in structuring food webs, ecosystem exchanges affecting species persistence and trophic interactions, and community responses and resilience to climate warming (Gauthier et al.). Finally, Hoy et al. used six decades of population and predation rate monitoring in a wolf-moose system in the United States, to present a novel approach for evaluating historical contingency in population ecology. Specifically, their synthesis demonstrates that the legacy of predation provides a reasonably powerful explanation of observed long-term population trends compared to alternate, theory-based models.

In sum, this Research Topic offers a small but important sample of recent advances and case studies related to long-term monitoring in ecology. These and other (see Likens, 1989; Gitzen et al., 2012; Lindenmayer and Likens, 2018) contributions reinforce the view that

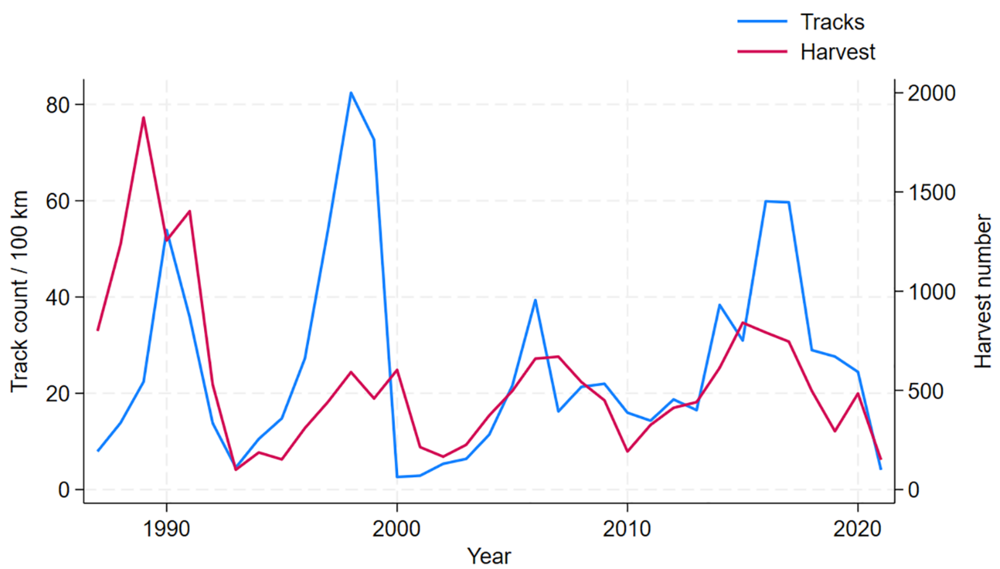

FIGURE 1
Correspondence between number of Canada lynx tracks counted per day, per 100 km near Kluane Lake, southwest Yukon, and number of lynx trapped for fur in Yukon Territory (1987-2002). Lynx track counts were obtained from a snowmobile transect surveyed each winter (Krebs et al.), and track counts can be converted to a population density estimate (O'Donoghue et al., 2022). Territorial lynx harvest rates lag track count data by 1 year (r = 0.65) and were obtained from Fur Institute of Canada (2024) and Statistics Canada (2024).

long-term monitoring remains relevant today, and that adoption of state-of-the-art techniques combined with sufficiently prolonged survey timelines will help ensure the future utility of this investigative approach for generating baseline data, tracking temporal changes, and supporting predictive models. Success of long-term monitoring programs will hinge on data quality and strength of inference, adoption and validation of untested survey approaches against independent data (e.g., Figure 1), strategic program design that maximizes efficiency and targets appropriate probes, as well as improved and reliable funding opportunities that value robust observational approaches (Lovett et al., 2007; Lindenmayer et al., 2022). Ultimately, long-term monitoring programs are an essential part of the ecological foundation to record the past and help forecast and possibly mitigate future trends.

Author contributions

DM: Writing – original draft, Writing – review & editing. CK: Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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