Received: 1 September 2025 | Accepted: 15 September 2025
DOI: 10.1111/1365-2656.70143

BRITISH ECOLOGICAL SOCIETY Journal of Animal Ecology

RESEARCH HIGHLIGHTS

Revealing species responses to environmental change through long-term data and mechanistic frameworks

Elise F. Zipkin[1,2] | Peter J. Williams[1,2]

[1]Department of Integrative Biology, Michigan State University, East Lansing, Michigan, USA
[2]Ecology, Evolution, and Behavior Program, Michigan State University, East Lansing, Michigan, USA

Correspondence
Elise F. Zipkin
Email: ezipkin@msu.edu

Handling Editor: Mariano Rodriguez-Cabal

Abstract

Research Highlight: Dri, G. F., Bogdziewicz, M., Hunter, M., Witham, J., & Mortelliti, A. (2025). Coupled effects of forest growth and climate change on small mammal abundance and body weight: Results of a 39-year field study. *Journal of Animal Ecology*. https://doi.org/10.1111/1365-2656.70114. Biodiversity is declining due to global environmental change, yet it remains challenging to assess how specific drivers, such as climate change, affect the dynamics and trends of individual species. While many studies correlate climate variables with species abundance or occurrence, few explicitly link environmental drivers to demographic processes to uncover the mechanisms behind population trends. Such insight requires long-term data capable of revealing slow-moving, nonlinear trends and disentangling natural variability from directional change. In a 39-year study, Dri et al. (2025) demonstrate the power of sustained observation and mechanistic approaches by linking climate warming and forest maturation to increased acorn production, which enhanced body condition and survival in white-footed mice, ultimately driving population increases. Their findings underscore the importance of long-term data for identifying meaningful ecological trends and tracing the causal pathways by which biodiversity changes. Effective conservation under global change depends on two key shifts: greater investment in long-term biodiversity monitoring and broader adoption of frameworks that explicitly connect environmental drivers to demographic responses. Together, these approaches provide the foundation for adaptive, evidence-based conservation strategies in a rapidly changing world.

KEYWORDS
biodiversity trends, conservation strategies, demographic mechanisms, long-term monitoring, population dynamics, resource pulses

In an era of rapid environmental change, understanding how animal populations respond to shifting climates and landscapes is a central challenge in ecology. Yet pinpointing the specific mechanisms by which these changes affect species-level dynamics remains difficult to resolve. Many studies of climate change, for example, predict species loss based on shifts in abiotic factors such as temperature and precipitation (Wiens & Zelinka, 2024). However, climate change influences more than just a species' climatic niche; it alters disturbance regimes (e.g. fires, extreme weather; Turner & Seidl, 2023), disrupts phenology (Renner & Zohner, 2018) and modifies species interactions including competition, predation and disease (Alexander et al., 2015; Angert et al., 2013). Despite wide-ranging effects, few

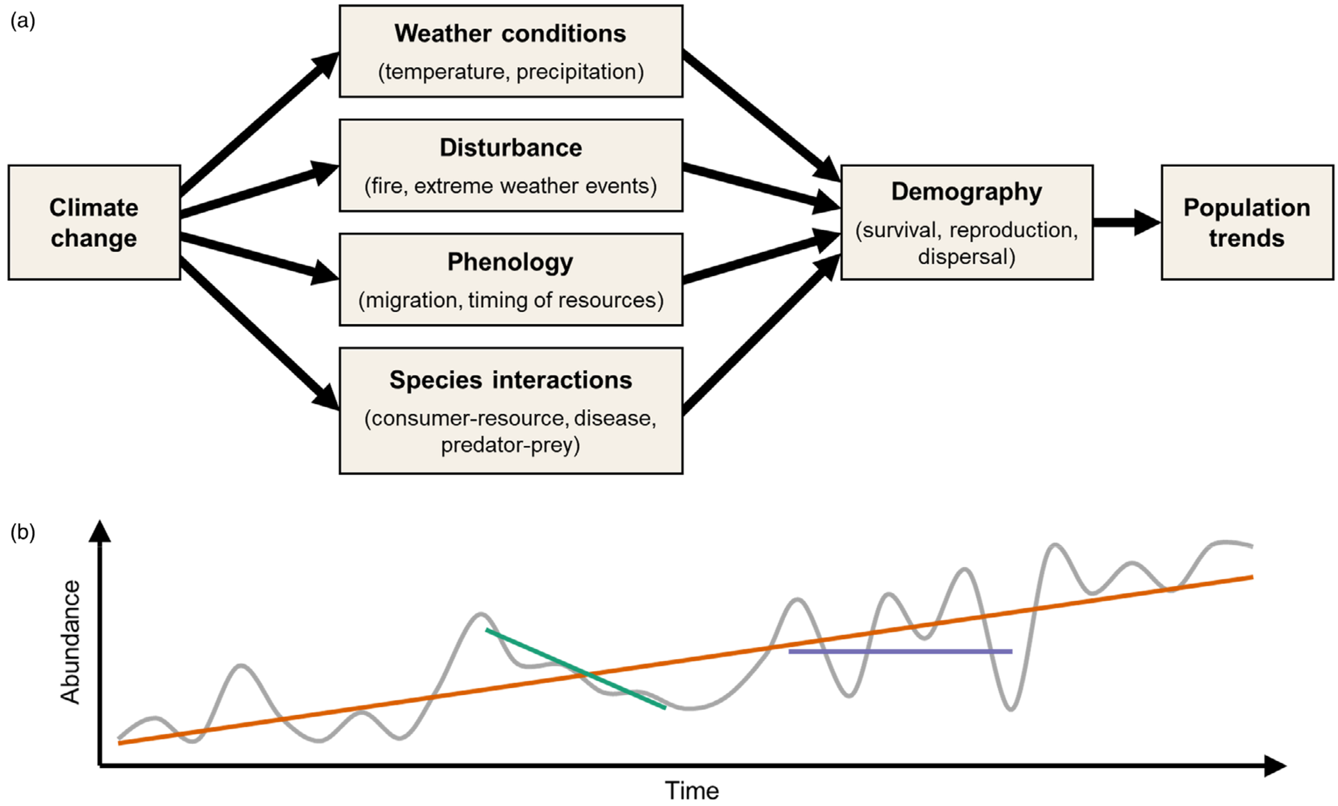

FIGURE 1 (a) Environmental change influences population trends through multiple, connected mechanisms. For example, climate change may affect species directly through weather conditions or indirectly through changes in disturbance, phenology and/or species interactions. The cascading effects of climate change work independently or together to alter species' demographic rates including survival and reproduction, which in turn determine population trends. (b) Long-term data are crucial for detecting species trends, especially when abundance is highly variable through time. For example, short-term studies could incorrectly detect a negative (green line) or stable trend (purple line), depending on the specific time during which a study occurs, when the actual long-term trend is positive (orange line).

studies link climate-driven changes to the demographic processes that underlie population trends (Jenouvrier 2013). Recent work has begun to address this gap by explicitly connecting environmental drivers to demographic mechanisms (Davis et al., 2025; Dunham et al., 2021; Malchow et al., 2023). To manage and conserve populations effectively, we need a more complete understanding of how climate and other forms of environmental change directly and indirectly influence demographic processes, both individually and in combination (Figure 1a).

Disentangling the complexities of environmental change impacts on populations requires long-term observational and/or experimental studies (defined here as research that relies on more than 20 years of data) to uncover the slow, nonlinear processes that shape population dynamics. Though resource-intensive, long-term studies move beyond snapshots to reveal patterns that would otherwise remain hidden. The value of long-term data has been demonstrated repeatedly across a wide range of ecosystems and research questions. Long-term studies have provided unparalleled insights into predator–prey dynamics (Krebs et al., 2018), community interactions (Silvertown et al., 2002), trophic cascades (Peterson et al., 2014) and the effects of disease, land use and climate on population cycles (Barroso et al., 2021; Jeger & Pautasso, 2008; Zylstra et al., 2021). Unlike short-term studies, which may be confounded by interannual variability, long-term research enables the detection of gradual trends, cyclical patterns and delayed responses that unfold over extended time periods.

A recent study by Dri et al. (2025) exemplifies the power of long-term data. Using four decades of observations, they link multiple related mechanisms, revealing a compelling story of how environmental change has driven population changes in white-footed mice (*Peromyscus leucopus*) in Maine, USA. As temperatures warmed and forests matured, acorn production increased. The increase in resource availability resulted in increased survival, ultimately leading to higher mouse abundance. Rather than simply correlating climate with abundance, Dri et al. (2025) show that climate and forest regeneration impact mice through the mechanism of resource availability, which then affects population trends through the mechanism of increased body mass, which leads to higher survival. This mechanistic approach has clear implications for management, as white-footed mice are the primary reservoir for Lyme disease (Roy-Dufresne et al., 2013). Understanding the demographic pathways that govern mice abundance can improve forecasts of disease risk.

Dri et al.'s (2025) mechanistic study was only possible thanks to the availability of long-term data—long-term tracking of tree

Journal of Animal Ecology

regeneration, acorn production, mouse weight and mouse abundance, as well as long-term, publicly available climate and weather records. Long-term data are essential for studying the population dynamics of white-footed mice, which experience boom–bust cycles driven by mast-seeding events. Individual red oak trees synchronize seed production, resulting in episodic resource pulses with widespread abundance of acorns in mast years but very few acorns in non-mast years. Masting systems can be highly unpredictable, both in timing and magnitude, making it difficult to detect trends without extended observations. Climate warming has altered both the synchrony and intensity of masting events in temperate forests, with warmer springs leading to more frequent and larger seed crops (Bogdziewicz et al., 2020). Because mouse population dynamics are tightly linked to masting patterns, Dri et al. (2025) showed that larger masts lead to a greater magnitude in the boom–bust cycles through time. Crucially, their data covered 10 full population cycles, allowing for differentiation between natural variability and directional change. A 5-year study, held at any point within the study period, would likely have missed these patterns entirely.

Detecting species trends, let alone attributing them to environmental change, is nearly impossible without sustained data collection. Monitoring programmes have been instrumental in documenting declines across a wide range of taxa (Dirzo et al., 2014), including insects (Bell et al., 2020) and birds (Rosenberg et al., 2019). Long-term monitoring data provide the statistical power necessary to detect subtle trends amidst the noise and variability inherent in population data (White & Bahlai, 2021). Many species decline gradually, often by just 1% or 2% annually, making such changes difficult to detect without extended time series. Even with 20 years of butterfly monitoring, Edwards et al. (2025) were unable to determine whether estimated changes in abundance—ranging from a 40% decline to a 90% increase over the study period—were statistically distinguishable from no change. Moreover, as Dri et al. (2025) demonstrated, many populations experience dramatic fluctuations, especially in variable environments (Tuljapurkar, 2013) or when resources are pulsed (Yang et al., 2010). This underscores a critical challenge in ecological research: short- and even medium-term studies may lack the resolution to detect subtle, yet meaningful population trends, especially when variability is high or sample sizes are limited (Figure 1b). Long-term monitoring not only improves statistical confidence but also allows researchers to separate transient fluctuations from systematic transitions. Without long-term data, we risk misinterpreting short-term patterns and overlooking the slow erosion of biodiversity.

To protect species from ongoing environmental change, two shifts are essential. First, we must invest more heavily in long-term biodiversity monitoring. Sustained data collection is the only way to uncover slow-moving trends, distinguish natural variability from directional change and establish ecological baselines. Long-term data are critical for achieving conservation objectives, evaluating management interventions and anticipating future changes. Tools like the Living Planet Index, which compiles long-term data across taxa and regions, are vital for tracking biodiversity and guiding international conservation priorities and policies (McRae et al., 2025). Second, we must adopt mechanistic frameworks that trace how environmental drivers affect specific demographic processes (e.g. survival, reproduction, dispersal) and how these processes interact to shape species trajectories. When applied to long-term datasets, mechanistic models can move beyond pattern detection to test competing hypotheses and identify causal pathways behind biodiversity change. Together, these approaches enable conservation strategies grounded in ecological understanding and more likely to succeed, while also enhancing capacity for adaptive decision-making.

AUTHOR CONTRIBUTIONS

E.F.Z. and P.J.W. co-wrote the article.

ACKNOWLEDGEMENTS

The authors used AI tools to edit the article.

CONFLICT OF INTEREST STATEMENT

The authors declares no conflict of interest.

DATA AVAILABILITY STATEMENT

There are no data associated with this manuscript.

ORCID

Elise F. Zipkin https://orcid.org/0000-0003-4155-6139
Peter J. Williams https://orcid.org/0000-0002-4806-2214

REFERENCES

Alexander, J. M., Diez, J. M., & Levine, J. M. (2015). Novel competitors shape species' responses to climate change. *Nature*, *525*, 515–518.

Angert, A. L., LaDeau, S. L., & Ostfeld, R. S. (2013). Climate change and species interactions: Ways forward. *Annals of the New York Academy of Sciences*, *1297*, 1–7.

Barroso, P., Acevedo, P., & Vicente, J. (2021). The importance of long-term studies on wildlife diseases and their interfaces with humans and domestic animals: A review. *Transboundary and Emerging Diseases*, *68*, 1895–1909.

Bell, J. R., Blumgart, D., & Shortall, C. R. (2020). Are insects declining and at what rate? An analysis of standardised, systematic catches of aphid and moth abundances across Great Britain. *Insect Conservation and Diversity*, *13*, 115–126.

Bogdziewicz, M., Kelly, D., Thomas, P. A., Lageard, J. G., & Hacket-Pain, A. (2020). Climate warming disrupts mast seeding and its fitness benefits in European beech. *Nature Plants*, *6*, 88–94.

Davis, K. L., Lanctot, R. B., Saalfeld, S. T., & Zipkin, E. F. (2025). Evaluating environmental drivers and synchrony of Arctic shorebird demographic rates to inform conservation management. *Ecological Applications*, *35*, e70049.

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J., & Collen, B. (2014). Defaunation in the Anthropocene. *Science*, *345*, 401–406.

Dri, G., Bogdziewicz, M., Hunter, M., Witham, J., & Mortelliti, A. (2025). Coupled effects of forest growth and climate change on small mammal abundance and body weight: Results of a 39-year field study. *Journal of Animal Ecology*. https://doi.org/10.1111/1365-2656.70114

Dunham, K. D., Tucker, A. M., Koons, D. N., Abebe, A., Dobson, F. S., & Grand, J. B. (2021). Demographic responses to climate change in a threatened Arctic species. *Ecology and Evolution*, *11*, 10627–10643.

Edwards, C. B., Zipkin, E. F., Henry, E. H., Haddad, N. M., Forister, M. L., Burls, K. J., Campbell, S. P., Crone, E. E., Diffendorfer, J., Douglas, M. R., & Schultz, C. B. (2025). Rapid butterfly declines across the United States during the 21st century. *Science*, *387*, 1090–1094.
Jeger, M. J., & Pautasso, M. (2008). Plant disease and global change: The importance of long-term data sets. *New Phytologist*, *1*, 8–11.
Jenouvrier, S. (2013). Impacts of climate change on avian populations. *Global Change Biology*, *19*, 2036–2057.
Krebs, C. J., Boonstra, R., Kenney, A. J., & Gilbert, B. S. (2018). Hares and small rodent cycles: A 45-year perspective on predator-prey dynamics in the Yukon boreal forest. *Australian Zoologist*, *39*, 724–732.
Malchow, A. K., Hartig, F., Reeg, J., Kéry, M., & Zurell, D. (2023). Demography–environment relationships improve mechanistic understanding of range dynamics under climate change. *Philosophical Transactions of the Royal Society B*, *378*, 20220194.
McRae, L., Cornford, R., Marconi, V., Puleston, H., Ledger, S. E., Deinet, S., Oppenheimer, P., Hoffmann, M., & Freeman, R. (2025). The utility of the Living Planet Index as a policy tool and for measuring nature recovery. *Philosophical Transactions B*, *380*, 20230207.
Peterson, R. O., Vucetich, J. A., Bump, J. M., & Smith, D. W. (2014). Trophic cascades in a multicausal world: Isle Royale and Yellowstone. *Annual Review of Ecology, Evolution, and Systematics*, *45*, 325–345.
Renner, S. S., & Zohner, C. M. (2018). Climate change and phenological mismatch in trophic interactions among plants, insects, and vertebrates. *Annual Review of Ecology, Evolution, and Systematics*, *49*, 165–182.
Rosenberg, K. V., Dokter, A. M., Blancher, P. J., Sauer, J. R., Smith, A. C., Smith, P. A., Stanton, J. C., Panjabi, A., Helft, L., Parr, M., & Marra, P. P. (2019). Decline of the North American avifauna. *Science*, *366*, 120–124.
Roy-Dufresne, E., Logan, T., Simon, J. A., Chmura, G. L., & Millien, V. (2013). Poleward expansion of the white-footed mouse (*Peromyscus leucopus*) under climate change: Implications for the spread of Lyme disease. *PLoS One*, *8*, e80724.
Silvertown, J., McConway, K. J., Hughes, Z., Biss, P., Macnair, M., & Lutman, P. (2002). Ecological and genetic correlates of long-term population trends in the park grass experiment. *The American Naturalist*, *160*, 409–420.
Tuljapurkar, S. (2013). *Population dynamics in variable environments* (Vol. *85*). Springer Science and Business Media.
Turner, M. G., & Seidl, R. (2023). Novel disturbance regimes and ecological responses. *Annual Review of Ecology, Evolution, and Systematics*, *54*, 63–83.
White, E. R., & Bahlai, C. A. (2021). Experimenting with the past to improve environmental monitoring. *Frontiers in Ecology and Evolution*, *8*, 572979.
Wiens, J. J., & Zelinka, J. (2024). How many species will Earth lose to climate change? *Global Change Biology*, *30*, e17125.
Yang, L. H., Edwards, K. F., Byrnes, J. E., Bastow, J. L., Wright, A. N., & Spence, K. O. (2010). A meta-analysis of resource pulse–consumer interactions. *Ecological Monographs*, *80*, 125–151.
Zylstra, E. R., Ries, L., Neupane, N., Saunders, S. P., Ramírez, M. I., Rendón-Salinas, E., Oberhauser, K. S., Farr, M. T., & Zipkin, E. F. (2021). Changes in climate drive recent monarch butterfly dynamics. *Nature Ecology & Evolution*, *5*, 1441–1452.

How to cite this article: Zipkin, E. F., & Williams, P. J. (2025). Revealing species responses to environmental change through long-term data and mechanistic frameworks. *Journal of Animal Ecology*, *94*, 2155–2158. https://doi.org/10.1111/1365-2656.70143