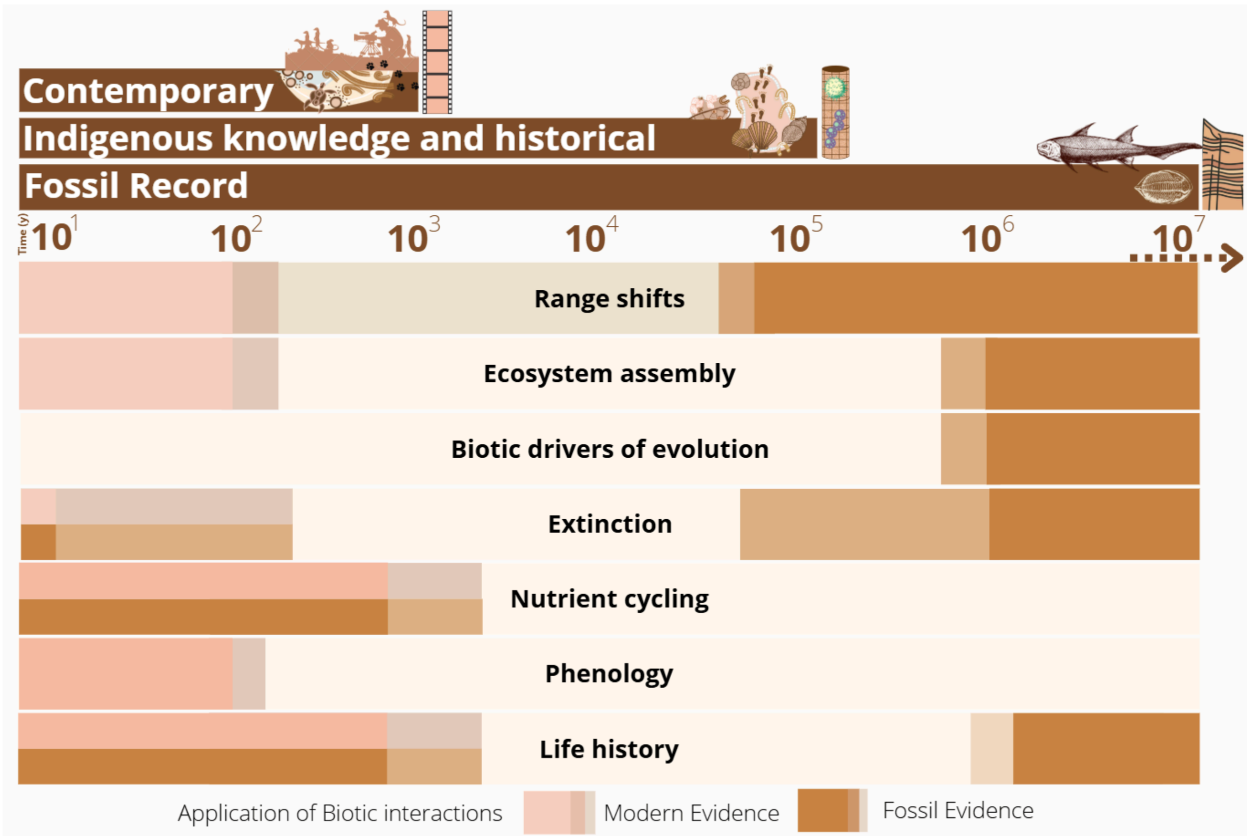
Scale: Crossing the Palaeo-Ecological Gap

Research on biotic interactions is divided by a persistent “scale gap” between ecological and palaeontological studies. Contemporary ecology, Indigenous knowledge, archaeology, and shallow-time records (e.g., lake or marine sediment cores) provide detailed insights into interactions over the past decades to millennia. Palaeontology, in contrast, can examine interactions over deep-time scales spanning millions of years. Between these two realms lies a critical interval, the ‘missing middle’ broadly from ~1000 years to ~100,000 years, that is often understudied (Fig1), in part due to the breaks between palaeontological and ecological information production, methodology, and data qualities). This interval encompasses major climatic transitions, cultural innovations, and extinction events, yet falls outside the reach of many ecological studies while lacking the temporal resolution of most fossil datasets. A recent study presented a framework for research prioritisation in collections science (Forbes et al, 2025). Under this framework the data that has the highest value of intimation and need of information are those in ‘*data-poor, high uncertainty, and high vulnerability’* conditions (Forbes et al. 2025). Figure 1 shows that crossing the palaeo-ecological gap in biotic interactions research falls into the priority sampling category of the framework. Consequently, not only is a dedicated database required to collate extant information, but more primary data collection is necessary to cross this gap.

Bridging this gap is essential for developing a continuous understanding of how biotic interactions evolve, persist, or collapse across timescales. Integrating evidence from deep, shallow, and contemporary records will enable researchers to trace ecological dynamics across orders of magnitude in time, linking short-term processes to their long-term consequences. Crossing the palaeo-ecological divide is therefore central to building a holistic view of biotic interactions and their role in shaping ecosystems through Earth history.

Figure 1 *A schematic illustrating the mismatch in temporal coverage. Modern datasets capture fine-scale processes, while fossil evidence anchors long-term trends, leaving the intermediate scale weakly resolved. Figure mottled after Kiessing et al (2025) and Finnigen et al (2024) for biotic interaction studies.*



Reference links per item

Research into biotic interactions was sought to provide a broad overview of research trends (Fig1). The majority of references below (Table1) informed the main paper but were not directly cited. The list is neither conclusive nor extensive. The majority of the published articles offer broad perspectives on biotic interactions either in scope or as a review, therefore for expansion see the reference list of each paper and the studies therein. The selected features are also indicative rather than representative of the scope of biotic interaction research.

Table 1: Example references for studies considering each temporal window. The list is intended as examples of the vast bodies of research available in each broad bracket on the temporal continuum of biotic interaction studies.

	Modern	**Shallow**	**Deep**
Range shifts	Potapov and Lewis, 2004; Schradin et al 2010	Zedeño, 2016	Price and Kirkpatrick 2009
Ecosystem assembly	Chesson 2000	Temperson et al 2016	Olszewski 2011; Chen et al, 2019
Biotic drivers of evolution	Amarasekare 2008; Poisot et al, 2011	Allaby et al 2022; Maier et al 2024	Lidgard et al, 2022
Extinction	Youngsteadt et al 2019	Crabtree et al 2021 Hernández-Yáñez 2022	Martins et al 2018
Nutrient cycling	Pringle et al 2023 Flores and Staal 2022	Bullen et al 2021	Vermeij 2019; Pires 2024
Phenology	Cerro and Holloway 2020; Meineke et al, 2021	Pau et al 2011; Maier et al 2023	Azevedo-Schmidt et al, 2022
Life history	Merten et al, 2021	Hernández-Yáñez et al, 2022; Médail and Pasta 2024	Labandeira and Wappler, 2023

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