Received: 29 May 2025 | Accepted: 19 June 2026

DOI: 10.1002/pan3.70388

BRITISH ECOLOGICAL SOCIETY People and Nature

REVIEW AND SYNTHESIS

Which biodiversity futures? Towards coherent design choices for scenarios exploring policy-relevant questions

Anita Lazurko[1] | Sarah Sinclair[1] | Jennifer A. Border[2] | Diana E. Bowler[3] | William H. Morgan[4] | James W. Pearce-Higgins[2,4,5] | Paul Woodcock[6] | Nick J. B. Isaac[3]

[1]UK Centre for Ecology & Hydrology, Lancaster, UK; [2]British Trust for Ornithology (BTO), Norfolk, UK; [3]UK Centre for Ecology & Hydrology, Oxfordshire, UK; [4]Department of Zoology, University of Cambridge, Cambridge, UK; [5]School of Biological Sciences, University of East Anglia, Norwich, UK and [6]Joint Nature Conservation Committee, Peterborough, UK

Correspondence
Anita Lazurko
Email: alazurko@ceh.ac.uk

Funding information
Joint Nature Conservation Committee

Handling Editor: Shonil A. Bhagwat

Abstract

1. Decision-makers are under pressure to take transformative action to address the biodiversity crisis. Scenarios can inform these decisions by exploring alternative future states of the world influencing biodiversity loss and the outcomes of actions to address it. However, amid significant methodological diversity, there is limited guidance regarding the scope of scenario design choices available and their suitability for particular applications. This gap generates a fragmented and opaque scenario landscape, hindering the inter-operability of scenarios and introducing the risk that projections or decisions are missing important risks or opportunities for transformative change.
2. We develop and validate a framework to facilitate coherent design choices (i.e. intentional, transparent and aligned with a question) for scenarios exploring biodiversity futures through two participatory workshops, a scoping review of relevant scenario studies and a retrospective case study reflection. We situate the framework in the United Kingdom as a case study with growing attention on scenarios to inform efforts to reverse centuries of biodiversity loss, but aim to ensure findings are generalisable.
3. The resulting framework guides users to build a flexible decision pathway including (1) a typology of key policy-relevant questions related to the future of biodiversity, (2) key design choices in the scenario approach and (3) a co-occurrence analysis that shows the prevalence of design choices for responding to policy-relevant questions, thereby highlighting more established design choices versus areas of novelty or innovation.
4. The retrospective case study reflection suggests how the framework can (a) facilitate a more intentional and transparent approach to using scenarios in ways that cater to the policy-relevant questions they are meant to answer, (b) expand options considered to explore a range of indirect and direct drivers of biodiversity loss

and (c) provide a common language to aid in communication across disciplines and perspectives.
5. Our findings suggest that flexible uptake of the framework can facilitate a more coherent and enriched scenario landscape, informing decisions that account for a wide range of risks to biodiversity and surfacing options for halting and reversing biodiversity loss.

KEYWORDS
conservation, ecosystem services, futures, governance, nature, pathways

1 | INTRODUCTION

The future of biodiversity and nature recovery is inherently complex and uncertain. Land use change, overexploitation of natural resources and pollution are driving the degradation, fragmentation and loss of habitats (Jaureguiberry et al., 2023; McCallum, 2015; Turvey & Crees, 2019). Climate change disrupts ecosystem structures and processes (IPCC, 2021) and the potential crossing of tipping points increases the possibility for non-linear impacts and cascading risks (Díaz et al., 2006; Lenton et al., 2023). Decision-makers are under pressure to take transformative action to halt and reverse biodiversity loss (IPBES, 2024), aligned with the Kunming-Montreal Global Biodiversity Framework (GBF) (Li et al., 2023).

In this context, scenarios are increasingly used to inform decision-making about the future of biodiversity. Scenarios are descriptions of possible future trajectories of a system, incorporating uncertain future conditions emerging from complex interactions across direct drivers of biodiversity loss (e.g. land use change, pollution), indirect drivers (e.g. social, economic and political systems) and/or alternative policy or management options (IPBES, 2016). Exploratory scenarios are agenda-setting tools to explore a wide range of outcomes, highlighting future risks and opportunities. In contrast, target-seeking scenarios define pathways of policy actions to reach a desired objective. Scenarios inform decision-making about biodiversity in numerous ways. They allow for increasingly rigorous projections that explore biodiversity outcomes under diverse climatic or socio-economic trajectories (Leclère et al., 2020; Pereira et al., 2024; Purvis, 2025) and inform investigation of the long-term consequences of strategic policy decisions aimed to reverse biodiversity loss (Jones et al., 2023; Peterson et al., 2003; Smith et al., 2023). Increasingly, scenarios are used to envision and build pathways towards nature positive futures, inspiring societal commitment to transformative action (Lazurko, de Pater, et al., 2025; Pereira et al., 2020).

The variety of scenario applications has stimulated significant methodological diversity. Scenario approaches span qualitative and quantitative data and expert-based and participatory methods, applied across sectors and spatial and temporal scales (Guaita et al., 2020; Kok et al., 2007; Kosow & Gaßner, 2008). The resulting scenarios are communicated as narrative storylines, diagrams of drivers and causal interactions, semi-quantitative or quantitative driver trends, or using creative and artistic methods. These outputs can directly inform decision-making or be further analysed in complex modelling chains that translate scenarios into quantitative biodiversity futures (Purvis, 2025). For example, land use models and integrated assessment platforms can quantify the effects of climate change and societal drivers on direct drivers of biodiversity loss, which are then fed into static pattern-based or complex process-based biodiversity models (Urban et al., 2022; Zurell et al., 2022).

This methodological diversity allows for tailored scenario approaches responding to diverse policy-relevant questions, but introduces new challenges. Because scenarios are tools for characterising uncertainty, not for making predictions of one most-likely future, no single approach can comprehensively depict the full complexity of the future (Abdelhakim et al., 2024). Moreover, challenges persist accounting for uncertainty and ambiguity in the influence of societal drivers of biodiversity loss (IPBES, 2016; Lazurko, Kim, et al., 2025), interactions with other environmental agendas like the climate crisis (Baldwin-Cantello et al., 2023; Pörtner et al., 2021; Smith et al., 2023) and the integration of diverse values and worldviews (Lundquist et al., 2021; Quintero-Uribe et al., 2022). In this context, design choices made in constructing the scenario approach strongly influence which future conditions and values are included or excluded and the suitability of scenarios for particular applications (Lazurko et al., 2023). We define design choices broadly as key choices made in the scenario framing, methodology or characterisation. For example, predictions of future species distributions depend on the time horizon (Bertelsmeier et al., 2013) and the spatial resolution of climate data (Trivedi et al., 2008). The choice of drivers in the scenarios also matters: for example, the Shared Socio-economic Pathways (SSPs) emerged to integrate socio-economics into climatic change science (e.g. Berkhout et al., 2002), yet the SSPs exclude biodiversity. Enriching the European SSPs with consideration of biodiversity reshaped the system dynamics and outcomes within the scenarios (Lazurko, Kim, et al., 2025).

General guidance for scientists and decision-makers to navigate the methodological diversity in scenario approaches is emerging (IPBES, 2016; Lazurko et al., 2023; Muiderman et al., 2022). Opaqueness around biodiversity modelling choices is also being addressed in some ecological disciplines (Gould et al., 2025; Zurell et al., 2020). However, this guidance is not specific to scenarios for nature-related, policy-relevant questions, perpetuating a fragmented scenario landscape that leaves the suitability of different approaches opaque. Thus, while methodological diversity is crucial, a lack of guidance and common language about design choices and their implications presents two interrelated risks: (1) decision-making processes using scenarios exclude consequential factors, with lasting material consequences (Lawrence et al., 2024); and (2) policy contexts may make narrow or unimaginative assumptions that constrain the ambition, inclusivity and effectiveness of strategic actions to achieve a sustainable future (Pereira et al., 2019). As a result, the usability and inter-operability of scenarios remain challenging for the scientific community, particularly amid efforts to produce more sophisticated long-term biodiversity projections underpinned by plausible or desirable societal trajectories (Leclère et al., 2020; Pereira et al., 2024).

In this paper, we develop and validate a framework that enables coherent design choices for scenarios exploring nature-related policy-relevant questions (i.e. intentional, transparent and aligned with the question). The framework aims to make design choices and assumptions explicit, informing a more coherent scenario landscape, widening and enriching the set of indirect and direct drivers of change considered in scenarios and enabling comparability across studies. To develop the framework, we draw on evidence globally to respond to the following questions through a case study in the United Kingdom. We use a mixed methods approach, combining two participatory workshops, a scoping review of relevant scenario studies and a retrospective case study reflection to ask:

1. What are the key policy-relevant questions related to the future of biodiversity in the UK that can be explored using scenarios?
2. What are the key design choices in scenario approaches related to (1)?
3. What is the prevalence of design choices (2) for responding to questions (1) in previous studies?
4. How could a framework synthesised from (1), (2) and (3) inform coherent design choices for scenarios related to the future of biodiversity in the UK?

We situate the case study in the United Kingdom (UK) as a policy context with growing interest in the use of scenarios (e.g. LUNZ Hub, n.d.; Benton et al., 2023; Minter et al., 2025; Pedde et al., 2021). The UK has been depleted by centuries of significant and ongoing habitat loss (Burns et al., 2023) and as a signatory to the GBF, the UK Government has committed to developing and implementing a National Biodiversity Strategy and Action Plan (Department of Agriculture, Environment and Rural Affairs, et al., 2025). However, there are ongoing concerns of governance and implementation gaps in achieving the UK's biodiversity targets (Rampling et al., 2024; The Office for Environmental Protection, 2024). Additionally, responsibility for nature and conservation is devolved to the four nations (England, Scotland, Wales and Northern Ireland), and each nation has established their own biodiversity and wider environmental action plans. In this context, there is growing demand for scenarios to inform nature-related policy action across jurisdictions, sectors and scales.

2 | METHODS

The iterative, mixed methods approach used to develop and validate the framework included two participatory workshops, a scoping review of scenario-related case studies and a retrospective case study reflection (Figure 1). The participatory aspects of the study received a favourable outcome from the UK Centre for Ecology and Hydrology Human Research Ethics Committee (Application Number: HREC00041). This included informed written participant consent. Participation was voluntary and individuals were free to withdraw at any stage with no consequence. Confidentiality and anonymity were protected, as identifiable information was anonymised for

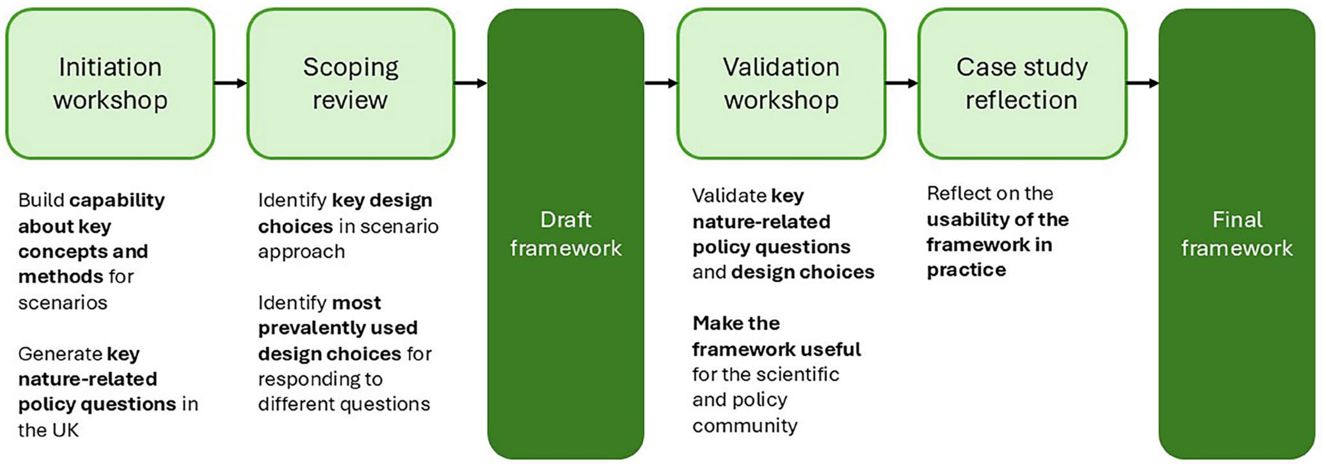

FIGURE 1 Methodology for developing and validating the framework for using scenarios to explore nature-related policy-relevant questions in the UK, presented sequentially from left to right.

analysis with original files deleted. Data protection and management protocols were in place, ensuring data were only accessible by the research team.

2.1 | Initiation workshop

A participatory workshop was held in February 2024 with biodiversity experts and policy/decision-makers in the UK. The aim was to build awareness about key concepts and methods for scenarios in environmental research and co-generate key questions related to biodiversity futures in the UK. The 23 participants in the workshop included 15 individuals from relevant academic partners, government departments, UK nature and conservation agencies and non-governmental organisations and 8 experts on scenarios and modelling of biodiversity futures. The workshop included an introduction to scenarios and a group brainstorming session to generate a long list of key questions about the future of biodiversity in the UK. These questions were collaboratively clustered on an axis from exploratory questions (i.e. about futures that could happen) to target-seeking questions (i.e. about futures we want to happen, pathways). The discussion was captured on a digital collaboration platform and by notetakers. The brainstorming of key questions was analysed using thematic content analysis to generate a typology of questions that served as input into the development of the framework.

2.2 | Scoping review

A scoping review of published scenario studies was conducted to (1) enrich the key policy-relevant questions related to biodiversity futures in the UK from the initiation workshop, (2) identify key design choices in the scenario approach (i.e. choices made in scenario framing, methodology and scenario characterisation) and (3) determine the prevalence of design choices for exploring particular policy-relevant questions. This third analysis was done to reverse engineer the logic of past design choices, assuming that higher prevalence offers some indication of more established design choices and lower prevalence indicates less established design choices. The scoping review was conducted to develop and validate a framework—not to synthesise the state-of-the-art—so the review is based on a representative and not comprehensive sample. This limitation was considered in the interpretation and discussion, with an emphasis that lower prevalence does not necessarily indicate whether a design choice is less *appropriate* as it can be attributed to other effects, such as relative ease of implementation or the need for methodological innovation.

The scoping review followed a process of abductive inquiry to synthesise findings into a framework for target users, rather than a systematic literature review. This involves 'inference to the best explanation', which is often used to formulate and initially test hypotheses develop theories (Walton, 2005), iterating between deductive (i.e. from general information to specific conclusions) and inductive (i.e. from specific observations to general conclusions) reasoning to synthesise information into a framework for target users.

2.2.1 | Literature search

The literature search obtained published interdisciplinary and transdisciplinary scenario studies related to biodiversity internationally and in the UK. Journal papers were obtained from Scopus (May–June 2024) using the following search terms and additional grey literature was obtained from participants involved in the Initiation Workshop and experts. The main search string for international case studies was (pathway* OR scenario*) AND (participatory OR interdisciplinar* OR transdisciplinar*) AND (biodiversity OR "ecosystem service*" OR natur*), with variants including (co-creat* OR co-product*) to obtain studies that engaged with stakeholders. The main search string for UK studies was (pathway* OR scenario*) AND (participatory OR interdisciplinar* OR transdisciplinar*) AND (biodiversity OR "ecosystem service*" OR nature) AND ("United Kingdom" OR England OR Scotland OR Wales OR "Northern Ireland"), with variants including (co-creat* OR co-product*). The title, abstract and keywords of the first 50 international papers and first 30 UK-specific papers were reviewed (to ensure global relevance with the case study in the UK) when sorted by relevance (as per Scopus), and the first 10 international and UK-specific papers were reviewed when sorted by publication date. The papers were selected if they had (a) a significant focus on scenario development and (b) clear methodological descriptions of how scenarios were developed and/or used. This excluded studies that simply varied the values of an environmental variable in a statistical model of a biodiversity outcome. This resulted in a selection of 43 global papers and 28 UK-specific papers. Grey literature suggestions were reviewed according to the same inclusion criteria as journal papers, resulting in an additional 24 studies.

2.2.2 | Literature analysis

The literature were analysed in MAXQDA, a qualitative data analysis software (VERBI Software, 2021), by two researchers using a deductive-inductive coding scheme. Researchers identified statements in the text that related to predetermined codes or themes (deductive), then allowed those codes to evolve throughout the analysis based on the underlying textual data (inductive). There were two types of predetermined codes: (a) the type of nature-related policy question, according to the typology derived from Workshop 1 and (b) themes of design choices, according to Lazurko et al. (2023). Codes were not mutually exclusive, wherein one study could contain multiple codes within the same theme. For example, many studies addressed multiple nature-related policy questions in different ways (i.e. nested choices), and some design choices occurred over time (i.e. sequential choices). During the coding process, some selected papers were excluded ($n=17$ global papers; 9 UK-specific papers) because they were not sufficiently detailed in their scenario approach or not sufficiently focused on biodiversity. A total of 26 global papers and 20 UK-specific papers were included in the final database. The full bibliographic information for these selected papers can be found in Data Sources.

After the first round of coding, codes were adjusted to reflect the textual data from the studies in the dataset. For example, an overarching code related to 'scenario type' was split into two to also highlight the 'target of modelling or evaluation'. These adjustments informed a second round of coding of all papers according to this adapted set of codes. Following this second round of coding, the researchers conducted a quality assurance process to ensure consistency and comprehensiveness of coding. One researcher then inductively analysed the textual statements under each code to identify and label sub-themes, aligned to the researchers' expert judgement. For example, statements under 'scenario type' were coded into sub-codes of 'agenda setting', 'policy design' and 'policy implementation', which reflected emergent themes in the literature but also aligned with IPBES terminology (see Table 2 for definitions). Similarly, statements under 'spatial scale' were split into sub-codes of 'local', 'regional/national' or 'global'. Once these sub-codes were complete and checked again for consistency, the database was finalised.

The database was analysed focusing on the document count (i.e. number of studies in the database coded to each code and sub-code) and co-occurrence analysis (i.e. number of studies in which two sub-codes co-existed simultaneously). The frequency of the co-occurrence of (a) the nature-related policy question and (b) the design choices indicate prevalence in the study database.

2.3 | Validation workshop

A participatory workshop with key biodiversity experts and policy/decision-makers in the UK was held in February 2025. The aim was to validate the framework to make it more usable and relevant. The 25 participants included 16 individuals from relevant academic partners, government departments, UK nature and conservation agencies and non-governmental organisations and 9 experts on scenarios and modelling of biodiversity futures. The discussion was captured on a digital collaboration platform and by notetakers. Participants validated the framework by voting on which questions in the final typology in the framework are most relevant to their organisation and how the question may need to be adapted to be useful. Participants then reviewed the design choices and gave feedback on the clarity and relevance of the descriptions. Then, participants enriched the framework by mapping existing and future scenario work onto the framework. After the process, participants were asked to share their experience of operationalising the framework. The feedback from participants was synthesised to inform the final iteration of the framework.

2.4 | Case study reflection

A retrospective reflection was conducted with seven experts from the co-author team to reflect on the potential opportunities and impact of using the framework in practice. The exercise focused on a protected area case study, which was selected because it was a more typical ecological modelling exercise that may benefit from an enriched scenario approach and addressed a timely and decision-relevant question that was established through stakeholder consultation. Additionally, the case study did not use a framework to inform their scenario approach, offering a useful basis from which to discuss opportunities to embed the framework in practice. The case study explored different structural ways of implementing the required increase in protected areas to reach 30% protected areas target in the UK under the Kunming-Montreal GBF, and the impacts this would have on bird abundance and trends (see Supporting Information for full case study description). During the reflection exercise, experts reflected on which questions their modelling approach asked, how the decision about these questions came about, and how the use of the framework may have influenced their approach. The experts then together reflected on their design choices, whether these decisions were made explicitly (e.g. through discussion) or implicitly (e.g. through the choice of modelling method), and how the use of the framework may have influenced them. These reflections are summarised in boxes throughout the presentation of results.

3 | RESULTS

3.1 | Scenarios are used to address a wide range of nature-related policy-relevant questions

The typology of key policy-relevant questions relevant to nature that can be explored using scenarios is summarised in Table 1. These questions fall into three broad types: (1) Evaluating risks and drivers related to biodiversity and nature positive, (2) Envisioning and elaborating desirable futures and (3) Understanding and evaluating options for change. Nine further sub-types are demonstrated with generalised example questions, which combine questions from the literature database and the Initiation Workshop. The count of documents from literature shows the number of studies (of 46) that were coded to that question type, noting that these questions are not mutually exclusive. The full analysis of studies according to these questions can be found in the Supporting Information (Table S1).

This analysis shows that questions related to *Understanding drivers* (57%); *Identifying, prioritising and phasing actions* (52%); and *Evaluating the effectiveness of management options* (52%) were most commonly addressed across UK and global studies and *Evaluating risks and uncertainty* (11%) and *Identifying robust solutions* (20%) were least represented. Comparing UK-specific versus global studies shows a prevalence in the UK for *Identifying and balancing multiple objectives & trade-offs* and *Evaluating the effectiveness and impacts of*

TABLE 1 Policy-relevant questions that can be explored using scenario approaches.

Category of question	Example questions	Document count (% of sample) Total	UK	Global
1. Evaluating risks and drivers associated with biodiversity and nature				
Understanding drivers	• What are the key social, cultural or technological drivers influencing future land use change, ecosystem services and biodiversity/nature outcomes? • What are the key biophysical drivers (e.g. climate change) influencing future land use change, ecosystem services and biodiversity/nature outcomes? • What land use change scenarios emerge from these interacting drivers? • What drivers of change (e.g. technological) influence future management options?	26 (57%)	11 (55%)	15 (58%)
Evaluating risk and uncertainty	• What are the critical risks and uncertainties associated with the future ecosystem services and biodiversity/nature outcomes? • How do these risks and uncertainties interact?	5 (11%)	1 (5%)	4 (15%)
2. Envisioning and elaborating desirable futures				
Monitoring change over time (methods & current indicators)	• What indicator(s) should be measured to assess progress towards a goal or desired biodiversity/nature outcome? • What indicator(s) should be measured to assess performance of policy and management strategies against a desired biodiversity/nature outcomes?	19 (41%)	7 (35%)	12 (46%)
Identifying and balancing multiple objectives & trade-offs	• What are the co-benefits and trade-offs of different ways of achieving multiple policy goals (e.g. for climate and biodiversity)? • How can we address conflicts between multiple goals (e.g. with synergistic policies)?	18 (39%)	9 (45%)	8 (31%)
Defining future biodiversity (visions & future indicators)	• What is our vision of a desirable future, that is a world in which we have achieved a desired biodiversity/nature outcome? • What indicators and targets/thresholds represent achieving that desirable future?	14 (30%)	6 (30%)	8 (31%)
3. Understanding and evaluating options for change				
Identifying, prioritising and phasing actions	• Which policies, management strategies or interventions are most suitable? • Where should these policies and management strategies be targeted? • How can these policies and management strategies be combined into pathways to achieve a desirable biodiversity/nature outcome?	24 (52%)	8 (40%)	15 (58%)
Evaluating the implications of change (e.g. land use)	• What are the implications of scenarios (e.g. of land use change or indirect drivers) on ecosystem services and biodiversity/nature outcomes? • What are the implications of changes in ecosystem services on human wellbeing? • Which social groups or regions are most affected by these changes?	13 (28%)	4 (20%)	9 (35%)
Evaluating the effectiveness and impacts of policy and management	• What are the impacts of individual or combinations of policy and management actions on biodiversity/nature and broader sustainability targets? • To what extent do the actions provide benefits and achieve their targets over time? • What are the co-benefits of actions? • Are there any trade-offs or unintended consequences of actions?	24 (52%)	12 (60%)	11 (42%)
Identifying robust solutions	• Which policies and management strategies are effective under a range of possible future scenarios? • Which policies and management strategies are feasible under a range of possible future scenarios?	9 (20%)	3 (15%)	6 (23%)

BOX 1 Key nature-related policy questions in the protected area case study in practice.

The protected areas case study explored questions such as: (1) 'What would happen to bird populations if the UK increased protected area coverage to 30% of its land area in different ways?', (2) 'What effect would targeted conservation management across those protected sites have on bird populations?' and (3) 'Would expanding protected area coverage to 30% with or without additional targeted management be sufficient to achieve nature recovery targets, such as increasing abundance by 2042 by 10%'? These questions fall under the Understanding and evaluating options for change category, including multiple questions under *Evaluating the effectiveness and impacts of policy and management*. These questions were co-developed through engagement with a range of actors in government, non-governmental organisations and statutory conservation agencies in the UK, considering the expertise of researchers and feasibility within resource constraints.

policy and management. Box 1 contains reflections on these questions from the protected area case study.

3.2 | Seven key design choices shape the scenario approach

Seven key design choices that shape the scenario approach are summarised in Table 2. For example, framing design choices may include the choice of *Scenario approach* or *Target of modelling and evaluation*, and methodological design choices may include the *Spatial scale* or *Level of quantification (formalisation)*. Each design choice is accompanied by a key question that may be asked when making the decision. Importantly, the construction of scenario approaches is more complex than implied by Table 2, because the design choices are not mutually exclusive. Many studies included multiple choices under a single design decision, as they may be done concurrently or in sequence: for example, a study may *evaluate the impact of indirect drivers (e.g. socio-economic change) on direct drivers (e.g. land use)* and subsequently *evaluate the impact of direct drivers (e.g. land use) on ecosystem services*. Additionally, design choices beyond the seven listed in Table 2 are possible and should be explored. The full analysis that codes the studies to these design choices can be found in Supporting Information (Table S2) alongside examples from the studies included in the scoping review for each design decision (Table S3).

From Table 2, prominent design choices (>60% of total studies) appear to use a *Policy design (target-seeking)* scenario approach (65%) and include *Direct (anthropogenic) drivers* (78%) and *Indirect drivers and/or policy levers* (70%) in the scenarios. Many studies are conducted at a *Regional Spatial scale* (61%) and are split between *Qualitative* (67%) and *Quantitative* (74%). These proportions were largely consistent at global and UK-specific studies, save for proportionally more studies characterising *Direct (biophysical) drivers* and *Medium-term* temporal scales in global studies. Similarly, proportionally more studies at global scales evaluated the *Impact of direct drivers (e.g. land use) on ecosystem services* and involved stakeholders for *Learning*, whereas more studies at UK scale evaluated the *Impact of direct drivers (e.g. land use) on biodiversity/nature outcomes*. Reflections on the design choices from the protected area case study are shared in Box 2.

3.3 | Co-occurrence of design choices and policy-relevant questions reveals important patterns

Table 4 presents the pairwise co-occurrence of design choices (row) and policy-relevant questions (column), with the number in each cell representing the number of studies coded to both. High prevalence is assumed to reflect more frequently explored questions (column) and more established design choices (row). Low prevalence is assumed to reflect less frequently explored questions and less established design choices, pointing to areas of novelty or innovation. Users should not assume lower prevalence is a direct indication of lower importance or appropriateness, as prevalence may also be attributed to other factors such as relative ease of implementation or publication bias.

Table 3 can be read in two directions. If a user's entry point is (a) a policy-relevant question they wish to answer, Table 3 can be read in the column direction to identify which design choices are most and least prevalently used. For example, studies responding to questions related to *Identifying, prioritising and phasing actions* for biodiversity predominantly used *Policy design (target-seeking)* scenario types (19 studies), using both anthropogenic *direct drivers* (16) and *indirect drivers* (15) that include policy and management options, and involved stakeholders for *Knowledge input* (18). If a user's entry point is (b) a design choice they want to use, Table 3 can be read in the row direction to identify most and least prevalent questions that approach has been used to answer. For example, modelling approaches that evaluate the *Impact of direct drivers on ecosystem services* most prevalently answer questions related to *Understanding drivers* (13 studies) and *evaluating the effectiveness and impacts of policy and management* (16). For each co-occurrence, users can consider whether they will make more established choices (high prevalence) or pursue more novel or innovative approaches (low prevalence).

From this starting point, Table 3 can also be used to explore additional relevant co-occurrences and examples and consider design choices and options beyond the scope of the framework. The full table of co-occurrence between design choices (not just policy-relevant questions to design choices, as in Table 3) can be found in

TABLE 2 Design choices in the construction and use of scenarios. The definition of each design decision is accompanied by a count of the number of studies coded to that design decision. Some studies did not report on some design choices, and many were coded to multiple design choices under the same theme. The order of presentation in the table is suggestive of a possible order in which choices may be made but is not prescriptive.

Design decision		Guiding question	Definition	Examples from studies	Number of studies		
					Total	UK	Global
Scenario approach (type)	Agenda setting (exploratory)	Which scenario approach/type is most useful for responding to the policy question?	Exploring a range of plausible futures, contributing to high-level problem identification and agenda setting	*Explore demographic, socio-economic and climatic scenarios to identify most susceptible ecosystem services in Barcelona* (De Luca et al., 2021)	24 (52%)	10 (48%)	14 (54%)
	Policy design (target-seeking)		Examining alternative policy or management options for achieving set targets, contributing to policy design	*Co-create and evaluate four pathways to achieving climate and biodiversity targets in collaboration with the Welsh government* (Jones et al., 2023)	30 (65%)	12 (60%)	17 (65%)
	Policy implementation (policy screening or evaluation)		Prospectively evaluating alternative policy, management or intervention options, contributing to policy implementation or evaluation	*Assess woodland management intervention bundles and their impact on ecosystem services in six sites across Scotland* (Eastwood et al., 2024)	14 (30%)	7 (33%)	7 (27%)
Types of drivers in scenarios	Direct drivers (anthropogenic, human-driven)	Which factors need to be included in the scenarios to respond to the policy question? (i.e. Which types of drivers are inside or outside of the system boundary?)	Human-related factors that directly impact biodiversity/nature, including through demands for ecosystem services	*Land use prioritisation* (Dang et al., 2021); *Peat extraction* (Saarikoski et al., 2019)	36 (78%)	15 (75%)	22 (85%)
	Direct drivers (environmental, biophysically driven)		Biophysical and biological factors that directly impact biodiversity/nature	*Response of semi-natural vegetation to changing climate* (Richards et al., 2023)	19 (41%)	6 (29%)	13 (50%)
	Indirect drivers and/or policy levers		Factors that indirectly impact biodiversity/nature by altering direct drivers or other indirect drivers, including by altering the policy and management landscape	*Agri-environmental change and rural policy* (Partidário et al., 2009); *Population levels, diets, food waste and agricultural imports and exports* (Smith et al., 2023)	32 (70%)	15 (75%)	16 (62%)
Target of modelling/evaluation	Impacts of indirect drivers and/or policy levers on direct drivers	What is the target of the evaluation informed by the scenarios? (i.e. what type of drivers are the scenarios comprised of, and against what effects are they being evaluated?)	Scenario processes that model or evaluate how changes to indirect drivers (including policy) impact the state of direct drivers (e.g. land use)	*Modelling how land use responds to different demographic paths and socio-economic situations to 2050* (Hallberg-Sramek et al., 2023)	22 (48%)	8 (40%)	13 (50%)
	Impacts of indirect drivers and/or policy levers on ecosystem services		Scenario processes that model or evaluate how changes to indirect drivers (including policy) impact ecosystem services, without evaluating biodiversity/nature outcomes directly	*Investigating future ecosystem service trade-offs under future landscape configurations* (Martínez-Sastre et al., 2017)	15 (33%)	5 (25%)	9 (35%)

TABLE 2 (Continued)

Design decision		Guiding question	Definition	Examples from studies	Number of studies: Total	UK	Global
	Impacts of direct drivers (e.g. land use) on ecosystem services		Scenario processes that model or evaluate how changes to direct drivers (e.g. land use) impact ecosystem services, without evaluating biodiversity/nature outcomes directly	*Estimating scenarios of land use, agriculture, infrastructure, tourism, equality, rural–urban dynamics and livelihoods impacts on ecosystem services* (Malinga et al., 2013)	26 (57%)	8 (38%)	18 (15%)
	Impacts of direct drivers (e.g. land use) on biodiversity/nature outcomes		Scenario processes that model or evaluate how changes to direct drivers (e.g. land use) impact nature by evaluating biodiversity/nature outcomes directly (e.g. through habitat or species modelling)	*Habitat suitability model for the crested ibis evaluated under different spatial configurations of land use* (Kabaya et al., 2019)	12 (26%)	8 (38%)	4 (15%)
	Impacts of indirect drivers and/or policy levers on management options		Scenario processes that model or evaluate how changes to indirect drivers impact the selection of management options (e.g. feasibility, preference, etc.)	*Using socio-economic analysis under different landscape change scenarios to understand cost-effectiveness of management options* (Sheate et al., 2008)	6 (13%)	3 (14%)	3 (12%)
Temporal scale	Short term	According to which time scale should our evaluation take place? (i.e. Which temporal dynamics are inside my system boundary?)	Time scale of approximately 5–10 years	*Sustainable intensification contrasted with enhanced protection of ecosystem services and multi-objective land use in agriculture from 2010 to 2020* (Southern et al., 2011)	5 (11%)	1 (5%)	4 (15%)
	Medium term		Time scale of approximately 10–25 years	*Woodland management scenarios evaluated over 20 years to coincide with the end of the site's management plan* (Eastwood et al., 2024)	11 (24%)	3 (14%)	8 (31%)
	Long term		Time scale of approximately 25 years or more	*Illustrative global nature positive scenarios developed to 2050 to align with the Convention of Biological Diversity commitments to 2050* (Durán et al., 2023)	18 (39%)	8 (40%)	9 (35%)
Spatial scale	Local	According to which spatial scale should our evaluation take place? (i.e. Which spatial dynamics are inside or outside of my system boundary?)	Spatial scale focused on a local area	*Deben Estuary in Suffolk, England* (Burdon et al., 2022)	18 (39%)	5 (24%)	13 (50%)
	Regional/national		Spatial scale focused on a region or nation	*Eastern Sierra Mountain Region, Spain* (Martínez-Sastre et al., 2017)	28 (61%)	13 (65%)	14 (54%)
	Global/international		Spatial scale focused on the international scale	*Global narratives of nature positive futures* (Durán et al., 2023)	2 (4%)	1 (5%)	1 (4%)

(Continues)

TABLE 2 (Continued)

Design decision		Guiding question	Definition	Examples from studies	Number of studies: Total	UK	Global
Level of stakeholder participation	Knowledge input	For what purpose should stakeholders be involved the scenario approach?	Stakeholders input their knowledge into an expert-defined process	*Participants fill in a questionnaire to clarify their views on most plausible outcomes for various drivers in 2050* (Kabaya et al., 2019)	39 (85%)	17 (85%)	21 (81%)
	Learning		Stakeholders engage with and learn from a scenario process, often including some form of knowledge co-production	*Deliberative participatory approach used to support stakeholders in investigating trade-offs between delivery of ecosystem service benefits* (Burdon et al., 2022)	7 (15%)	5 (24%)	8 (31%)
	Validation		Stakeholders validate the outcomes of a scenario process	*Validation of scenarios done through a stakeholder survey* (Blancas et al., 2018)	13 (28%)	2 (10%)	5 (19%)
Level of quantification (formalisation)	Qualitative	To what extent are the scenarios and their implications quantified, and at what stage in the analysis?	Scenario process does not formalise knowledge, for example producing storylines, narratives and visuals of change	*Cause and effect relationships in scenarios analysed using qualitative mind maps* (Kumar et al., 2013)	31 (67%)	12 (60%)	18 (69%)
	Semi-quantitative		Scenario process somewhat formalises knowledge, for example doing semi-quantitative assessments of change	*Ecosystem service outcomes under different scenarios analysed on a scale of substantial negative to substantial positive change*, that is −−, −, 0, +, ++ (Malinga et al., 2013)	20 (43%)	7 (33%)	13 (50%)
	Quantitative		Scenario process formalises knowledge, for example quantifying and modelling change	*Multiple climatic and land use scenarios modelled using an integrated model of an upland landscape of New Zealand* (Richards et al., 2023)	34 (74%)	15 (75%)	18 (69%)

BOX 2 Key design choices in the protected area case study in practice.

The *Scenario approach* emerged from the policy-relevant questions, which included both *Policy screening and evaluation* and *Target seeking*. The 30 × 30 policy stipulates that 30% of land is protected by 2030 (i.e. a policy lever or indirect driver), which requires a change of existing protected area management or the introduction of new protected areas. The *Target of the modelling /Evaluation* therefore focused on the impacts and consequences of the changes to the extent of protection of specific land areas—protected areas, and the degree of conservation management targeted at those protected areas. These were classed as direct drivers of species abundance and trends of bird species, falling under the *Impacts of direct drivers (e.g. land use) on biodiversity/nature outcomes* category. The case study selected a *Medium term (~12 years)* time scale due to initial engagement, as users wanted to evaluate the effects of progress towards the 2030 target on protected area extent and the implications for species' abundance targets to 2042. The *Spatial scale* was determined by the focus on national policy and the resolution of the available spatial data (*National*, 1 km^2). The *Level of stakeholder participation* for producing the scenarios themselves was 'none' or 'validation' according to the framework, as stakeholders were engaged in the study framing and in validating and discussing results, but not in the construction of scenarios or implementation of the modelling. The *Level of quantification* was high as statistical modelling was the focus of the study.

Supporting Information (Table S4), in addition to the more comprehensive series of example studies.

3.4 | The findings can inform coherent design choices for scenarios exploring biodiversity futures

This section translates the findings of the review into a methodological framework to enable coherent design choices that are intentional, transparent and aligned with the question they are meant to answer.

3.4.1 | Coherent design choices

The methodological framework in Table 4 suggests how the review findings presented in Sections 3.1–3.3 can be used to enable coherent design choices in future studies. Step 1 requires scanning the scope of options available for policy-relevant questions that can be explored using scenarios (Table 1) and design choices (Table 2). This informs Step 2, in which a user identifies their entry point, which allows them to then explore the co-occurrence analysis in Step 3 (Table 3) in ways that suit their needs. Step 4 expands on this initial exploration of co-occurrence, suggesting users go beyond their entry point to consider additional co-occurrences and seek example studies as needed. At this point, a user can mix and match design choices, making careful decisions regarding whether to use more established (high prevalence) or novel (low prevalence) approaches depending on the overall purpose of the study and capabilities of the team. In some cases, users may also be prompted to test options beyond the scope of the framework.

These decisions must keep in mind factors beyond appropriateness that may influence the prevalence of particular design choices (e.g. researcher skillset, implementation feasibility or publication bias). Step 5 is to embark on a decision pathway, involving a series of intentional and transparent decisions building from the entry point established in Step 2, drawing from the insights from Steps 1 to 4. Within the decision pathway, a user will select at least one policy-relevant question to answer and at least one option for each of the seven design choices. Importantly, this process can be fluid as users may approach this process from multiple entry points with different priorities, capacities and constraints.

3.4.2 | Example decision pathways

We visualise part of a decision pathway from two contrasting entry points to demonstrate the concept: (a) a policymaker with an initial policy question they want to explore (Figure 2) and (b) a biodiversity modeller with a method they want to use to inform policy (Figure 3).

The first decision pathway (Figure 2) is from the perspective of a policymaker with an initial policy question they want to explore using scenarios. One of the categories of questions ranked highest in importance in the validation workshop was *Understanding drivers* (e.g. what are the key social, cultural or technological drivers influencing future land use change, ecosystem services and biodiversity/nature outcomes?). The decision pathway shows a possible route through design choices that follow, starting with *Scenario approach*, followed by *Types of drivers in scenarios*, *Target of modelling/evaluation* and *Level of quantification (formalisation)*. From this, we can see how a user may construct a decision pathway considering the full range of options (boxes) and co-occurrences between the policy-relevant question (thickness of lines).

The second decision pathway (Figure 3) is based on the perspective of a biodiversity modeller who wishes to provide evidence for policy. In this example, the decision pathway is less linear, as it starts from a design choice—the *Target of modelling/evaluation*—which then is connected upward to the questions the approach may answer and downward to the choice of *Scenario approach*. In this way, the framework allows modellers to be more

TABLE 3 Count of documents with indicated co-occurrence of codes in the database, reflecting which design choices from Table 2 (row) have been used more frequently to respond to particular questions from Table 1 (columns).

Design decision	Evaluating risks to biodiversity and nature positive: Understanding drivers	Evaluating risks to biodiversity and nature positive: Evaluating risks	Envisioning and elaborating desirable futures: Monitoring change over time	Envisioning and elaborating desirable futures: Multiple objectives & trade-offs	Envisioning and elaborating desirable futures: Defining future biodiversity	Understanding and evaluating options for change: Identifying, prioritising and phasing actions	Understanding and evaluating options for change: Evaluating the implications of change	Understanding and evaluating options for change: Evaluating the impacts of policy	Understanding and evaluating options for change: Identifying robust solutions
Scenario approach (type)—*Which scenario approach/type has been (should be) used for responding to the policy question?*									
Agenda setting (exploratory)	18	3	9	10	6	10	9	11	4
Policy design (target-seeking)	13	2	12	10	11	19	10	16	8
Policy implementation (policy screening or evaluation)	4	2	8	5	2	7	2	10	3
Types of drivers in scenarios—*Which factors have been (should be) included in the scenarios to respond to the policy question? (i.e. Which types of drivers have been/should be inside or outside of the system boundary?)*									
Direct drivers (anthropogenic, human-driven)	16	4	14	14	14	16	8	20	5
Direct drivers (environmental, biophysically driven)	13	3	6	3	4	9	8	8	4
Indirect drivers and/or policy levers	20	1	13	11	9	15	10	12	5
Target of modelling/evaluation—*What has been (should be) the target of the evaluation informed by the scenarios? (i.e. what type of drivers have /should the scenarios be comprised of, and what effects have been/should be evaluated?)*									
Impacts of indirect drivers and/or policy levers on direct drivers	12	1	10	9	7	8	7	11	4
Impacts of indirect drivers and/or policy levers on ES	6	1	4	3	2	9	4	5	4
Impacts of direct drivers (e.g. land use) on ES	13	3	12	12	7	11	10	16	5
Impacts of direct drivers (e.g. land use) on biodiversity/nature	5	1	6	8	3	5	3	10	2
Implications of indirect drivers and/or policy levers on management	5	1	3	2	2	5	2	2	2

TABLE 3 (Continued)

Design decision	Evaluating risks to biodiversity and nature positive		Envisioning and elaborating desirable futures			Understanding and evaluating options for change			
	Understanding drivers	Evaluating risks	Monitoring change over time	Multiple objectives & trade-offs	Defining future biodiversity	Identifying, prioritising and phasing actions	Evaluating the implications of change	Evaluating the impacts of policy	Identifying robust solutions
Temporal scale—*According to which time scale has/should the evaluation take place? (i.e. Which temporal dynamics are inside of my system boundary?)*									
Short term	4	1	2	2	2	4	2	2	1
Medium term	8	0	6	4	2	4	5	6	2
Long term	9	2	5	7	5	6	3	7	3
Spatial scale—*According to which spatial scale has/should the evaluation take place? (i.e. Which spatial dynamics are inside or outside of my system boundary?)*									
Local	10	3	8	10	7	10	6	11	5
Regional/National	16	2	12	6	6	12	8	11	4
Global	0	0	0	0	1	0	0	1	0
Level of stakeholder participation—*For what purpose has/should stakeholders be involved the scenario approach?*									
Knowledge input	22	3	14	12	13	18	10	17	9
Validation	9	1	6	5	4	5	5	6	3
Learning	4	1	3	3	4	5	1	5	2
Level of quantification (formalisation)—*To what extent has/should the scenarios and their implications quantified, and at what stage in the analysis?*									
Qualitative	17	3	12	12	10	16	11	13	6
Semi-quantitative	13	3	8	6	5	9	9	9	6
Quantitative	18	3	17	14	9	15	11	19	6

Note: Cell colour scheme ranges from highest document count (most prevalent) in green to lowest document count (least prevalent) in red across the full dataset. Questions for each design decision are worded in the past (referring to future studies) and future (to guide future studies). The order of presentation of the design choices (rows) is suggestive of a possible order in which choices may be made but is not prescriptive. The order of presentation of the columns is irrelevant.

TABLE 4 Methodological framework to guide coherent design choices for scenarios in future studies.

Step	Activity		Relevant data
1. Scan options	Review the key policy-relevant questions and design choices to understand full range of options available.		Tables 1 and 2
2. Determine entry point	Determine whether the entry point to scenarios is: (a) a policy-relevant question to answer (b) a certain design choice to use (e.g. modelling approach)		
3. Explore options co-occurring with the entry point	*If entry point is (a)* Read the co-occurrence table in the column direction to identify the prevalence of design choices responding to the question and to find exemplar studies.	*If entry point is (b)* Read the co-occurrence table in the row direction to identify the prevalence of questions the design choice has answered and to find exemplar studies.	Table 3
4. Explore additional relevant co-occurrences and examples	Building on Step 3, explore additional co-occurrences in Table 3 and the co-occurrence between design choices in the Supporting Information. Refer to example studies in the Supporting Information for further insight as needed. For each co-occurrence, consider whether more established (high prevalence) or less established or novel approaches (low prevalence) are preferred, aligned to the a user's overall aims and priorities. Remain open minded to emerging decision choices from literature beyond (Table 4).		Table 3; Supporting Information
5. Design a coherent decision pathway	Using insight from Step 3 and 4, make a series of intentional and transparent decisions building from the entry point. At the end of the decision pathway, a user will have: • Selected at least one policy-relevant questions to answer • Selected at least one option for each of the seven design choices		Tables 3 and 4; Supporting Information; Figures 2 and 3

intentional with which types of scenarios they can use and which policy-relevant questions they can answer. Box 3 summarises reflections connecting design choices to policy-relevant questions in the protected area case study.

4 | DISCUSSION

The Kunming-Montreal GBF outlines an ambitious trajectory for transformative action as an urgent response to biodiversity loss (Convention on Biological Diversity, 2022; Li et al., 2023). Addressing the implementation gap between targets, plans and action requires translating these ambitions into context-relevant and implementable policy and management strategies that account for the wide range of complexities and uncertainties influencing the future of biodiversity. Various research projects and government agencies in the UK and globally are developing scenarios to underpin biodiversity projections in response, many of which are detailed in the 26 global and 20 UK-specific studies. However, no single scenario approach addresses the full scope of complexity influencing the future of biodiversity, highlighting the importance of coherent design choices for biodiversity futures.

In this paper, we developed and validated a methodological framework comprised of five steps to enable these coherent design choices. By coherent, we mean design choices that are intentional, transparent and aligned with the question they are meant to answer. The framework ends with a user constructing a fluid decision pathway that builds on their exploration of three findings from our study: a typology of key policy-relevant questions relevant to the future of biodiversity, a series of key design choices required to construct and use scenarios, and a co-occurrence analysis indicating more and less prevalent design choices for responding to particular questions. By making the range of options and choices in a decision pathway explicit, this framework expands the scope of options and promotes more purposive choices, mitigating the risk that decisions informed by scenarios exclude important risks or opportunities (Lawrence et al., 2024). This intentional and transparent approach may also help challenge or nuance assumptions and enable transformative action. Importantly, flexible use of the framework is needed to accommodate multiple entry points and the influence of real-world factors that make design decisions more context-dependent and fluid in practice. Still, widespread uptake of the framework could offer common terminology and a shared understanding across organisations, disciplines and sectors, including between scientific and policy communities. In doing so, the framework can provide greater structure and transparency, thus improving the usability and inter-operability of scenarios for the scientific community.

The findings can be operationalised by diverse users developing and using scenarios to explore biodiversity futures. The primary use of the methodological framework is to guide design choices in future studies according to the steps detailed in Section 3.4. Key to these steps is that the framework can be approached from multiple entry points: for example, a policymaker who has a question they wish to answer or a scientist who has an approach they want to use. Within the UK, the framework can be considered representative of the scenario landscape in published studies and used accordingly. Users at local scales within the UK may consider adapting the questions in the framework, as they were elicited from primarily national-level stakeholders from statutory bodies. Beyond the UK, the framework can be considered relatively generalisable. However, users may consider adapting the framework by enriching it with local or regional studies

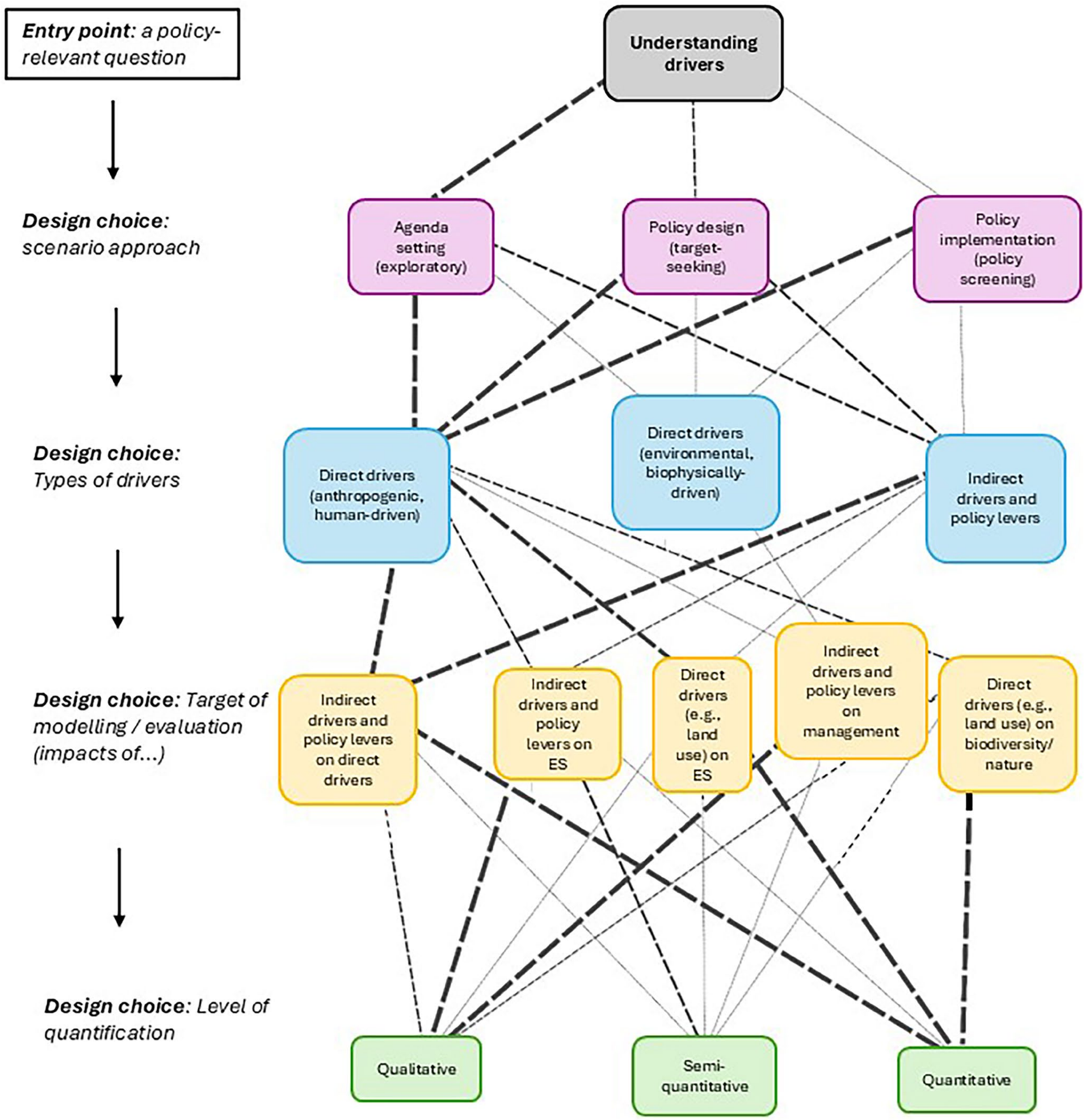

FIGURE 2 A decision pathway, where a user makes a series of design choices, starting from the key policy question they wish to answer. The strength of co-occurrence of the two connecting nodes is represented by the thickness of the line, indicating relative prevalence in the study database and suggesting more established methods. By contrast, thinner lines represent less tested design choice options. ES, ecosystem services.

and reflecting upon the unique aspects of their social-ecological and political context. Participatory methods can help contextualise the policy-relevant questions. For example, where action to address the biodiversity crisis has become politically challenging, users may need to alter the wording of the questions to suit their environment or add additional questions that addresses socio-political tensions as a key driver of biodiversity futures (Billet et al., 2024; Le Velly et al., 2024). Users may also need to innovate beyond the scope of existing studies to address emergent challenges and add additional design choices that reflect their needs. For example, some contexts may call for inclusive scenario approaches that centre Indigenous and local communities (Chibwe et al., 2024). Others may wish to leverage creative arts, imagination, emotions and values in the scenario process, which has been published less frequently in the UK and were thus underrepresented in this study (Fazey et al., 2020; Moore & Milkoreit, 2020; Pereira et al., 2019).

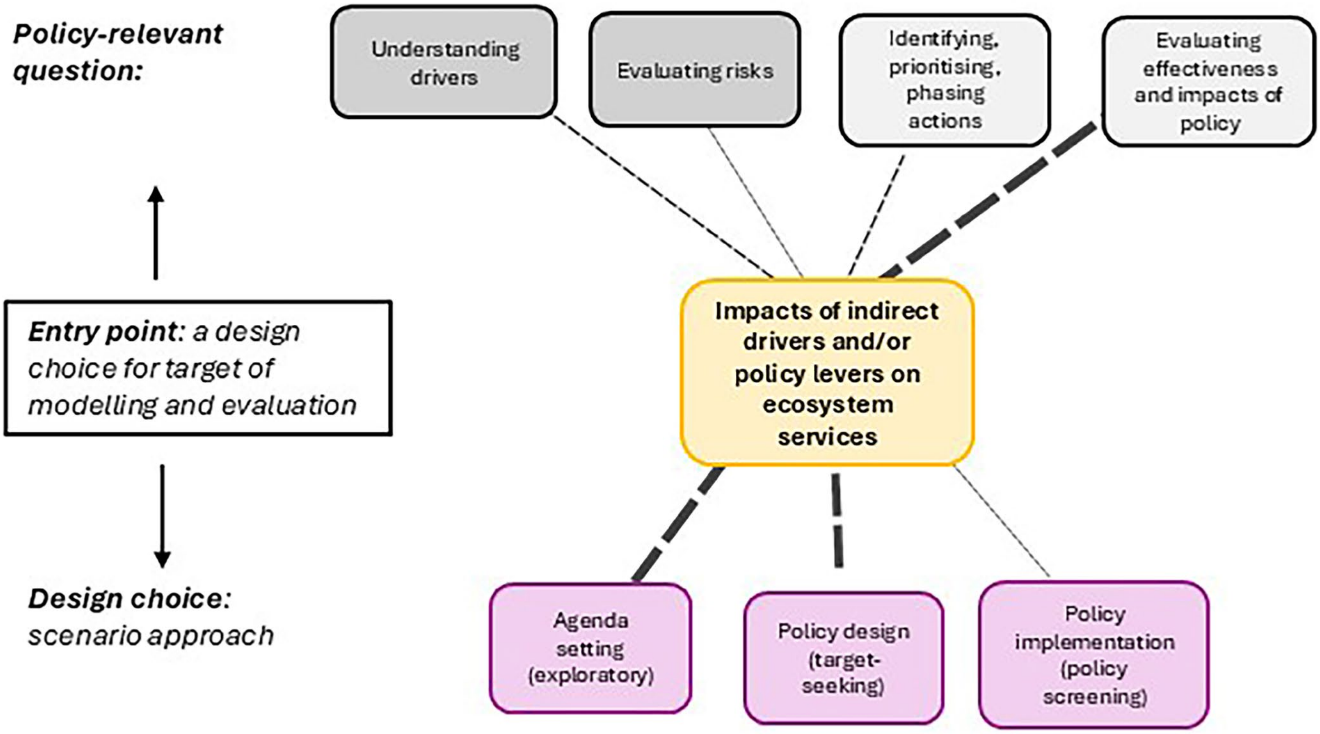

FIGURE 3 Decision pathway from the design decision 'target of modelling and evaluation' (orange box) to the policy-relevant question (grey boxes) and scenario approach (purple boxes). The strength of co-occurrence of the two connecting nodes is represented by the thickness of the line, indicating relative prevalence in the study database.

BOX 3 Connecting design choices to policy-relevant questions in the protected area case study in practice.

The protected area case study responded to questions about Understanding and evaluating options for change, that is *Evaluating the effectiveness and impacts of policy and management*. Table 3 shows that the most prevalent design choices that respond to these questions include using *Policy design (target-seeking)* scenario approaches (16 co-occurrences), including *Direct drivers (anthropogenic, human-driven)* (20 co-occurrences), with the *Target of the modelling and evaluation* focused on the *Impacts of direct drivers (e.g. land use) on ES* (16 co-occurrences). These design choices deviate from the actual decisions made in the protected area case due to the contextual factors—such as stakeholder preferences, data availability and researcher capacities and expertise. Co-authors reflected that using the framework when developing their case study may have helped them consider additional options beyond those immediately surfaced by decision-makers. The framework may have offered a clearer structure for scoping follow-on work, such as an evaluation of co-benefits and trade-offs of conservation actions (*Identifying and balancing multiple objectives and trade-offs*) or of their effectiveness under multiple land use or climatic trajectories (*Evaluating the effectiveness and impacts of policy and management*). Using the framework may have helped co-authors consider expanding or altering the scope of the study to include different scenario approaches or types of drivers, which may be addressed in future developments of the modelling framework (e.g. exploratory scenarios evaluating how a policy related to timber or food self-sufficiency in the UK may impact land cover and thus the locations and effectiveness of protected area sites). These reflections point to the potential benefits of coherent approach but also emphasise that the framework can guide—but not dictate—design choices due to the nuances of real-world factors.

Our framework can also be used in other ways within the biodiversity research community. Retrospective reflection on previous studies can help communicate how existing scenario approaches are situated relative to others, expanding the framework as needed if additional questions or design choices emerge. This is particularly useful for the modelling community, as greater transparency about the assumptions in societal trajectories informing biodiversity projections can build legitimacy and aid in interpretation of the outputs. The co-occurrence analysis also reveals emergent patterns to inform a future research agenda. For example, questions related to *Understanding drivers*; *Identifying, prioritising and phasing actions*; and *Evaluating the effectiveness of management options* were most commonly addressed across UK and global studies and *Evaluating risks and uncertainty* and *Identifying robust solutions* were least represented. Addressing such gaps may help improve the resilience and long-term effectiveness of nature-related policy.

The study had several limitations that should be considered in uptake and further research. A limited number of studies were available to underpin the framework, elicited through search terms that returned inter/transdisciplinary studies with a significant focus on scenario development. This search process did not aim to be wholly comprehensive but provide sufficient data for generating the framework. This means that the study should be considered non-comprehensive to serve as a foundation for more comprehensive meta-analysis of a wider scope of studies and to further innovation in methods beyond the scope of this framework. Additionally, the search criteria excluded studies that lacked methodological detail on the scenarios themselves, which in many cases excluded modelling studies that simply varied the values of an environmental variable in a statistical biodiversity model. As a result, we did not close the gap between scenario development (which characterises the direct and indirect drivers of biodiversity loss) with the quantitative projections estimating impacts on biodiversity. Future research to elaborate on design choices for particular modelling approaches would be valuable. This limitation mirrors a gap in this field of research that needs to be addressed, between the community of scientists pursuing methodological rigour and innovation in scenario development from those attempting to improve biodiversity modelling approaches for long-term projections. Opportunities to leverage scenarios as a way to facilitate integration across scientists has been documented (Kröger & Schäfer, 2016) and can be further leveraged here.

Another limitation of our study is that we used a retrospective analysis of past scenario studies to inform a framework that guides future studies. This has significant implications, as it bounds the set of questions and design choices to past studies without considering crucial, emergent issues. For example, biodiversity futures are influenced by highly complex interactions between social and ecological systems. Many existing scenario approaches simplify the non-linear, emergent nature of change in linked social-ecological systems, particularly under emerging conditions in which humans are a dominant force influencing the earth system (Folke et al., 2021; Verburg et al., 2016). Similarly, dominant scenario approaches have only recently begun to embrace the plurality of worldviews and value systems (Leventon et al., 2021; Pereira et al., 2021). These crucial challenges are not reflected in this study due to our search terms and our reliance on published work at the time of analysis.

Second, the co-occurrence analysis in particular relied on the assumption that higher prevalence (i.e. a higher count of documents with a specific co-occurring policy-relevant question and design choice) is indicative of more established design choices. Conversely, we assumed that lower prevalence is indicative of less established design choices, which offer areas of novelty or innovation. We avoided making an explicit assumption that low prevalence indicates a design choice is explicitly less *appropriate*, as lower prevalence may be a result of other factors, including challenges or trade-offs of implementing particular design choices in practice as emerged in the case study reflection. For example, many ecologists may be more comfortable with the scientific conventions of quantitative models and find more qualitative or semi-quantitative approaches challenging even though they may be the only options available. Certain design choices also may require significantly more resources: considering a wider range of indirect socio-economic drivers introduces significant complexity and uncertainty to the modelling process. Thus, users have been encouraged to intentionally choose to either adopt more established or novel approaches and to draw from examples in the study database to support their decisions as needed. Future studies may consider other methods that better link prevalence with appropriateness, such as using expert judgement or multiple performance metrics to further validate and enrich our approach.

5 | CONCLUSION

Scenarios are useful tools for characterising the complexity and uncertainty influencing biodiversity futures, but the methodological diversity of the field presents challenges. In this study, we developed and validated a framework for coherent design choices for scenarios that explore policy-relevant questions using a mixed methods approach, including two participatory workshops, scoping review and case study reflection. This resulted in a typology of nature-related, policy-relevant questions to be explored using scenarios, a series of seven key design choices that make up a scenario approach and a co-occurrence analysis that shows the prevalence of design choices responding to particular questions. Together, these inform a five-step methodological approach that guides a user towards a bespoke decision pathway of design choices that meet their needs.

This study opens up several areas for future research. The framework can be populated with both current and emerging studies that did not appear in the published study database, helping develop a more comprehensive framework and database that can be used to identify gaps that more accurately chart pathways for future research in the UK and beyond. The framework could also be translated into an interactive decision pathway via a user interface, which can support uptake of the framework (e.g. a user can choose an entry point and structure their own decision pathway based on the database underlying the framework). Further research is required to test the impact of the framework in real-world scenario processes, to determine whether it leads to better outcomes and improves the inter-operability and coherence of the scenario landscape. This opportunity can be inspired by emerging efforts to improve and trace the impact of using models for evidence-based decision-making through structured approaches in conservation science (Addison et al., 2013; Burgman et al., 2011). Further research is also required to adapt the framework to new contexts—other countries and sub/international scales—and potentially other sectors beyond biodiversity.

Because this was a non-comprehensive review, future studies can conduct more comprehensive meta-analysis of studies structured by our framework and further innovation in methods beyond the scope of this framework.

Biodiversity, both in the UK and globally, has been significantly depleted over recent centuries, and numerous efforts to generate evidence for informing decisions to halt and reverse biodiversity loss using scenarios are underway. Our framework guides coherent design decisions for scenarios exploring biodiversity futures, demonstrated in the UK to explore how such a framework can be made relevant and operational for a particular policy landscape. The resulting framework can facilitate a more intentional and transparent approach to making design choices that are commensurate with the questions asked. The use of the framework will also help policymakers map the evidence available and understand why studies might differ in their inference. This will enable greater use of inter-model comparisons as climatologists do, which will help improve clarity with respect to the consistency of evidence for decision-making. In summary, we suggest that consistent uptake and enrichment of the framework hold promise for generating evidence that can facilitate a more coherent and potentially transformative set of options for halting and reversing biodiversity loss.

AUTHOR CONTRIBUTIONS

Anita Lazurko and Sarah Sinclair conceived the ideas and designed methodology; Anita Lazurko and Sarah Sinclair collected and analysed data for the scoping review. Anita Lazurko, Sarah Sinclair, Diana E. Bowler, William H. Morgan, James W. Pearce-Higgins, Paul Woodcock and Nick J. B. Isaac collected and analysed data during participatory workshops. Anita Lazurko, Sarah Sinclair, Jennifer A. Border, William H. Morgan, James W. Pearce-Higgins, Paul Woodcock and Nick J. B. Isaac participated in the case study reflection. Anita Lazurko and Sarah Sinclair led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

ACKNOWLEDGEMENTS

This study was conducted as part of the Biodiversity Pathways project, a project funded by the UK Joint Nature Conservation Committee that aims to build the foundations of a modelling framework for projecting biodiversity futures. Thank you to the members of the Biodiversity Pathways Project Advisory Committee and participants of the two participatory workshops for your insightful contributions.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

All data generated in the study is included in the manuscript. For transparency, the full analysis of literature is included in the Supporting Information. As the publication is open access, it can be directly used and has not been archived.

STATEMENT ON INCLUSION

The study included a global and regional (UK) review of secondary data, which did not include any local data collection and involved scientists of numerous disciplinary backgrounds. Primary data was collected to contextualise the review in the United Kingdom through workshops, which is reflected in the participant recruitment and geographical distribution of the author team.

ORCID

Anita Lazurko https://orcid.org/0000-0003-3313-4091
James W. Pearce-Higgins https://orcid.org/0000-0003-1341-5080

REFERENCES

Abdelhakim, D., Stevance, A.-S., & Bridgewater, P. (2024). *A guide to anticipation: Working paper on tools and methods of horizon scanning and foresight*.

Addison, P. F. E., Rumpff, L., Bau, S. S., Carey, J. M., Chee, Y. E., Jarrad, F. C., McBride, M. F., & Burgman, M. A. (2013). Practical solutions for making models indispensable in conservation decision-making. *Diversity and Distributions*, *19*, 490–502. https://doi.org/10.1111/ddi.12054

Baldwin-Cantello, W., Tickner, D., Wright, M., Clark, M., Cornelius, S., Ellis, K., Francis, A., Ghazoul, J., Gordon, J. E., Matthews, N., Milner-Gulland, E. J., Smith, P., Walmsley, S., & Young, L. (2023). The triple challenge: Synergies, trade-offs and integrated responses for climate, biodiversity, and human wellbeing goals. *Climate Policy*, *23*, 782–799. https://doi.org/10.1080/14693062.2023.2175637

Benton, T., Curry, A., Fredenburgh, J., Macmillan, T., Bridle, S., Bellamy, A. S., Kepinski, S., & Ward, N. (2023). *UK AGRI-food system what could the look like in 2050?* UK Food Systems Programme Project on Cultured Meat and Farmers.

Berkhout, F., Hertin, J., & Jordan, A. (2002). Socio-economic futures in climate change impact assessment: Using scenarios as 'learning machines'. *Global Environmental Change*, *12*, 83–95. https://doi.org/10.1016/S0959-3780(02)00006-7

Bertelsmeier, C., Luque, G. M., & Courchamp, F. (2013). The impact of climate change changes over time. *Biological Conservation*, *167*, 107–115. https://doi.org/10.1016/j.biocon.2013.07.038

Billet, M. I., Baimel, A., Milfont, T. L., & Norenzayan, A. (2024). Political common ground on preserving nature: Environmental motives across the political Spectrum. *Environment and Behavior*, *56*, 542–576. https://doi.org/10.1177/00139165241303315

Burgman, M., Carr, A., Godden, L., Gregory, R., McBride, M., Flander, L., & Maguire, L. (2011). Redefining expertise and improving ecological judgment. *Conservation Letters*, *4*, 81–87. https://doi.org/10.1111/j.1755-263X.2011.00165.x

Burns, F., Mordue, S., Al-Fulaij, N., Boersch-Supan, P., Boswell, J., Boyd, R. J., Bradfer-Lawrence, T., de Ornellas, P., de Palma, A., de Zylva, P., Dennis, E. B., Foster, S., Gilbert, G., Halliwell, L., Hawkins, K., Haysom, K. A., Holland, M., Hughes, J., Jackson, A. C., … Gregory, R. D. (2023). *State of nature 2023*.

Chibwe, B., Terry, N., Noumonvi, K. D., Carpenter-Urquhart, L., Tcheton, S., & Pereira, L. (2024). African futures: A review of scenarios for indigenous and local people and nature in Africa. *Ecology and Society*, *29*, art32. https://doi.org/10.5751/ES-15322-290332

Convention on Biological Diversity. (2022). *Decision adopted by the conference of the parties to the convention on biological diversity 15/4. Kunming-Montreal Global Biodiversity Framework*. Conference of the Parties to the Convention on Biological Diversity.

Department of Agriculture, Environment and Rural Affairs, Scottish Government, Welsh Government, & UK Government. (2025).

Blueprint for halting and reversing biodiversity loss: the UK's national biodiversity strategy and action plan for 2030.

Díaz, S., Fargione, J., Chapin, F. S., III, & Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS Biology*, *4*, e277.

Fazey, I., Schäpke, N., Caniglia, G., Hodgson, A., Kendrick, I., Lyon, C., Page, G., Patterson, J., Riedy, C., Strasser, T., Verveen, S., Adams, D., Goldstein, B., Klaes, M., Leicester, G., Linyard, A., McCurdy, A., Ryan, P., Sharpe, B., … Young, H. R. (2020). Transforming knowledge systems for life on earth: Visions of future systems and how to get there. *Energy Research and Social Science*, *70*, 101724. https://doi.org/10.1016/j.erss.2020.101724

Folke, C., Polasky, S., Rockström, J., Galaz, V., Westley, F., Lamont, M., Scheffer, M., Österblom, H., Carpenter, S. R., Chapin, F. S., III, Seto, K. C., Weber, E. U., Crona, B. I., Daily, G. C., Dasgupta, P., Gaffney, O., Gordon, L. J., Hoff, H., Levin, S. A., … Walker, B. H. (2021). Our future in the Anthropocene biosphere. *Ambio*, *50*, 834–869. https://doi.org/10.1007/s13280-021-01544-8

Gould, E., Fraser, H. S., Parker, T. H., Nakagawa, S., Griffith, S. C., Vesk, P. A., Fidler, F., Hamilton, D. G., Abbey-Lee, R. N., Abbott, J. K., Aguirre, L. A., Alcaraz, C., Aloni, I., Altschul, D., Arekar, K., Atkins, J. W., Atkinson, J., Baker, C. M., Barrett, M., … Zitomer, R. A. (2025). Same data, different analysts: Variation in effect sizes due to analytical decisions in ecology and evolutionary biology. *BMC Biology*, *23*, 35. https://doi.org/10.1186/s12915-024-02101-x

Guaita, N., Mart, J., & Fitz, C. (2020). Environmental scenario analysis on natural and social-ecological systems: A review of methods, approaches and applications. *Sustainability*, *12*, 7542. https://doi.org/10.3390/su12187542

IPBES. (2016). *The methodological assessment report on scenarios and models of biodiversity and ecosystem services*.

IPBES. (2024). In K. O'Brien, L. Garibaldi, A. Agrawal, E. Bennett, O. Biggs, R. Calderón Contreras, E. Carr, N. Frantzeskaki, H. Gosnell, J. Gurung, S. Lambertucci, J. Leventon, C. Liao, V. Reyes García, L. Shannon, S. Villasante, F. Wickson, Y. Zinngrebe, & L. Perianin (Eds.), *Summary for policymakers of the thematic assessment report on the underlying causes of biodiversity loss and the determinants of transformative change and options for achieving the 2050 vision for biodiversity of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES secretariat.

IPCC. (2021). Summary for policymakers. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, & R. Yu (Eds.), *Climate change 2021: The physical science basis. Contribution of working group I to the sixth assessment report of the Intergovernmental Panel on Climate Change*. IPCC.

Jaureguiberry, P., Titeux, N., Wiemers, M., Bowler, D. E., Coscieme, L., Golden, A. S., Guerra, C. A., Jacob, U., Takahashi, Y., Settele, J., Díaz, S., Molnár, Z., & Purvis, A. (2023). The direct drivers of recent global anthropogenic biodiversity loss. *Science Advances*, *8*, eabm9982. https://doi.org/10.1126/sciadv.abm9982

Jones, S. M., Smith, A. C., Leach, N., Henrys, P., Atkinson, P. M., & Harrison, P. A. (2023). Pathways to achieving nature-positive and carbon–neutral land use and food systems in Wales. *Regional Environmental Change*, *23*, 37. https://doi.org/10.1007/s10113-023-02041-2

Kok, K., Biggs, R., & Zurek, M. (2007). Methods for developing multiscale participatory scenarios: Insights from Southern Africa and Europe. *Ecology and Society*, *12*, 8. https://doi.org/10.5751/ES-01971-120108

Kosow, H., & Gaßner, R. (2008). *Methods of future and scenario analysis: Overview, assessment, and selection criteria*. Studies/Deutsches Institut für Entwicklungspolitik.

Kröger, M., & Schäfer, M. (2016). Scenario development as a tool for interdisciplinary integration processes in sustainable land use research. *Futures*, *84*, 64–81. https://doi.org/10.1016/j.futures.2016.07.005

Lawrence, M., Homer-Dixon, T., Janzwood, S., Rockström, J., Renn, O., & Donges, J. F. (2024). Global polycrisis: The causal mechanisms of crisis entanglement. *Global Sustainability*, *7*, e6. https://doi.org/10.1017/sus.2024.1

Lazurko, A., de Pater, M., Kim, H., Hebinck, A., Biesbroek, R., DeClerck, F., Krupnik, S., Okruszko, T., Pereira, L. M., Proka, A., Sakellari, E., & Harrison, P. A. (2025). Envisioning nature-positive futures for Europe: Inspiring transformative change at the biodiversity nexus. *Ecosystems and People*, *21*, 2561107. https://doi.org/10.1080/26395916.2025.2561107

Lazurko, A., Kim, H., Linney, G., Díaz-General, E., Vaňo, S., Harmáčková, Z. V., Rounsevell, M., & Harrison, P. A. (2025). Enriching the European shared socio-economic pathways with considerations of biodiversity and nature using a nexus approach. *Climate Risk Management*, *50*, 100741. https://doi.org/10.1016/j.crm.2025.100741

Lazurko, A., Schweizer, V., Pintér, L., & Ferguson, D. (2023). Boundaries of the future: A framework for reflexive scenario practice in sustainability science. *One Earth*, *6*, 1703–1725. https://doi.org/10.1016/j.oneear.2023.10.027

Le Velly, G., Delacote, P., Golden Kroner, R. E., Keles, D., & Pfaff, A. (2024). Politics driving efforts to reduce biodiversity conservation in the United States. *Ecology and Society*, *29*, 27. https://doi.org/10.5751/ES-15338-290327

Leclère, D., Obersteiner, M., Barrett, M., Butchart, S. H. M., Chaudhary, A., de Palma, A., DeClerck, F. A. J., di Marco, M., Doelman, J. C., Dürauer, M., Freeman, R., Harfoot, M., Hasegawa, T., Hellweg, S., Hilbers, J. P., Hill, S. L. L., Humpenöder, F., Jennings, N., Krisztin, T., … Young, L. (2020). Bending the curve of terrestrial biodiversity needs an integrated strategy. *Nature*, *585*, 551–556. https://doi.org/10.1038/s41586-020-2705-y

Lenton, T. M., McKay, D. I. A., Loriani, S., Abrams, J. F., Lade, S. J., Donges, J. F., Milkoreit, M., Powell, T., Smith, S. R., Zimm, C., Buxton, J. E., Bailey, E., Laybourn, L., Ghadiali, A., & Dyke, J. G. (2023). *Global tipping points summary report 2023*.

Leventon, J., Duşe, I. A., & Horcea-Milcu, A.-I. (2021). Leveraging biodiversity action from plural values: Transformations of governance systems. *Frontiers in Ecology and Evolution*, *9*, 609853.

Li, Q., Ge, Y., & Sayer, J. A. (2023). Challenges to implementing the Kunming-Montreal global biodiversity framework. *Land*, *12*, 2166. https://doi.org/10.3390/land12122166

Lundquist, C., Hashimoto, S., Denboba, M. A., Peterson, G., Pereira, L., & Armenteras, D. (2021). Operationalizing the nature futures framework to catalyze the development of nature-future scenarios. *Sustainability Science*, *16*, 1773–1775. https://doi.org/10.1007/s11625-021-01014-w

LUNZ Hub. (n.d.). *Land use for net zero hub*. Retrieved February 12, 2026, from https://lunzhub.com/

McCallum, M. L. (2015). Vertebrate biodiversity losses point to a sixth mass extinction. *Biodiversity and Conservation*, *24*, 2497–2519. https://doi.org/10.1007/s10531-015-0940-6

Minter, M., Baker, S., Bowditch, E., Carlisle, S., Constant, N., Syder, A., & Finch, T. (2025). Using participatory scenario planning to explore the synergies and trade-offs from upland treescape expansion. *People and Nature*, 1–15. https://doi.org/10.1002/pan3.70025

Moore, M. L., & Milkoreit, M. (2020). Imagination and transformations to sustainable and just futures. *Elementa*, *8*, 1–17. https://doi.org/10.1525/elementa.2020.081

Muiderman, K., Zurek, M., Vervoort, J., Gupta, A., Hasnain, S., & Driessen, P. (2022). The anticipatory governance of sustainability transformations: Hybrid approaches and dominant perspectives. *Global Environmental Change*, *73*, 102452. https://doi.org/10.1016/j.gloenvcha.2021.102452

Pedde, S., Harrison, P. A., Holman, I. P., Powney, G. D., Lofts, S., Schmucki, R., Gramberger, M., & Bullock, J. M. (2021). Enriching the shared socioeconomic pathways to co-create consistent multi-sector scenarios for the UK. *Science of the Total Environment*, *756*, 143172. https://doi.org/10.1016/j.scitotenv.2020.143172

Pereira, H. M., Martins, I. S., Rosa, I. M. D., Kim, H., Leadley, P., Popp, A., van Vuuren, D. P., Hurtt, G., Quoss, L., Arneth, A., Baisero, D., Bakkenes, M., Chaplin-Kramer, R., Chini, L., Di Marco, M., Ferrier, S., Fujimori, S., Guerra, C. A., Harfoot, M., … Alkemade, R. (2024). Global trends and scenarios for terrestrial biodiversity and ecosystem services from 1900 to 2050. *Science (New York, N.Y.)*, *384*, 458–465. https://doi.org/10.1126/science.adn3441

Pereira, L., Sitas, N., Ravera, F., Jimenez-Aceituno, A., & Merrie, A. (2019). Building capacities for transformative change towards sustainability: Imagination in intergovernmental science-policy scenario processes. *Elementa: Science of the Anthropocene*, *7*, 35. https://doi.org/10.1525/elementa.374

Pereira, L. M., Davies, K. K., den Belder, E., Ferrier, S., Karlsson-Vinkhuyzen, S., Kim, H. J., Kuiper, J. J., Okayasu, S., Palomo, M. G., Pereira, H. M., Peterson, G., Sathyapalan, J., Schoolenberg, M., Alkemade, R., Ribeiro, S. C., Greenaway, A., Hauck, J., King, N., Lazarova, T., … Lundquist, C. J. (2020). Developing multiscale and integrative nature – People scenarios using the nature futures framework. *People and Nature*, *2*, 1–24. https://doi.org/10.1002/pan3.10146

Pereira, L., Kuiper, J. J., Selomane, O., Aguiar, A. P. D., Asrar, G. R., Bennett, E. M., Biggs, R., Calvin, K., Hedden, S., Hsu, A., Jabbour, J., King, N., Köberle, A. C., Lucas, P., Nel, J., Norström, A. V., Peterson, G., Sitas, N., Trisos, C., … Ward, J. (2021). Advancing a toolkit of diverse futures approaches for global environmental assessments. *Ecosystems and People*, *17*, 191–204. https://doi.org/10.1080/26395916.2021.1901783

Peterson, G. D., Cumming, G. S., & Carpenter, S. R. (2003). Scenario planning: A tool for conservation in an uncertain world. *Conservation Biology*, *17*, 358–366. https://doi.org/10.1046/j.1523-1739.2003.01491.x

Pörtner, H. O., Scholes, R. J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W. L., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C., Hickler, T., Hoegh-Guldberg, O., … Ngo, H. T. (2021). *IPBES-IPCC co-sponsored workshop biodiversity and climate change workshop report*.

Purvis, A. (2025). Bending the curve of biodiversity loss requires a 'satnav' for nature. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, *380*, 20230210. https://doi.org/10.1098/rstb.2023.0210

Quintero-Uribe, L. C., Navarro, L. M., Pereira, H. M., & Fernández, N. (2022). Participatory scenarios for restoring European landscapes show a plurality of nature values. *Ecography*, *2022*, e06292. https://doi.org/10.1111/ecog.06292

Rampling, E. E., zu Ermgassen, S. O. S. E., Hawkins, I., & Bull, J. W. (2024). Achieving biodiversity net gain by addressing governance gaps underpinning ecological compensation policies. *Conservation Biology*, *38*, e14198. https://doi.org/10.1111/cobi.14198

Smith, A. C., Harrison, P. A., Leach, N. J., Godfray, H. C. J., Hall, J. W., Jones, S. M., Gall, S. S., & Obersteiner, M. (2023). Sustainable pathways towards climate and biodiversity goals in the UK: The importance of managing land-use synergies and trade-offs. *Sustainability Science*, *18*, 521–538. https://doi.org/10.1007/s11625-022-01242-8

The Office for Environmental Protection. (2024). *Progress in improving the natural environment in England 2022/2023*.

Trivedi, M. R., Berry, P. M., Morecroft, M. D., & Dawson, T. P. (2008). Spatial scale affects bioclimate model projections of climate change impacts on mountain plants. *Global Change Biology*, *14*, 1089–1103. https://doi.org/10.1111/j.1365-2486.2008.01553.x

Turvey, S. T., & Crees, J. J. (2019). Extinction in the Anthropocene. *Current Biology*, *29*, R982–R986.

Urban, M. C., Travis, J. M. J., Zurell, D., Thompson, P. L., Synes, N. W., Scarpa, A., Peres-Neto, P. R., Malchow, A. K., James, P. M. A., Gravel, D., de Meester, L., Brown, C., Bocedi, G., Albert, C. H., Gonzalez, A., & Hendry, A. P. (2022). Coding for life: Designing a platform for projecting and protecting global biodiversity. *Bioscience*, *72*, 91–104. https://doi.org/10.1093/biosci/biab099

VERBI Software. (2021). MAXQDA [Computer software]. https://www.maxqda.com

Verburg, P. H., Dearing, J. A., Dyke, J. G., Leeuw, S., Seitzinger, S., Steffen, W., & Syvitski, J. (2016). Methods and approaches to modelling the Anthropocene. *Global Environmental Change*, *39*, 328–340. https://doi.org/10.1016/j.gloenvcha.2015.08.007

Walton, D. (2005). *Abductive reasoning*. The University of Alabama Press.

Zurell, D., Franklin, J., König, C., Bouchet, P. J., Dormann, C. F., Elith, J., Fandos, G., Feng, X., Guillera-Arroita, G., Guisan, A., Lahoz-Monfort, J. J., Leitão, P. J., Park, D. S., Peterson, A. T., Rapacciuolo, G., Schmatz, D. R., Schröder, B., Serra-Diaz, J. M., Thuiller, W., … Merow, C. (2020). A standard protocol for reporting species distribution models. *Ecography*, *43*, 1261–1277. https://doi.org/10.1111/ecog.04960

Zurell, D., König, C., Malchow, A.-K., Kapitza, S., Bocedi, G., Travis, J., & Fandos, G. (2022). Spatially explicit models for decision-making in animal conservation and restoration. *Ecography*, *2022*, e05787. https://doi.org/10.1111/ecog.05787

DATA SOURCES

Global studies for scoping review

Asante-Yeboah, E., Koo, H. M., Ros-Tonen, M. A. F., Sieber, S., & Fürst, C. (2024). Participatory and spatially explicit assessment to envision the future of land-use/land-cover change scenarios on selected ecosystem services in Southwestern Ghana. *Environmental Management*, *74*(1), 94–113. https://doi.org/10.1007/s00267-024-01943-z

Blancas, A. N. I., la Torre-Cuadros, M. D. L. Á., & Carrera, G. A. M. (2018). Using foresight to gain a local perspective on the future of ecosystem services in a mountain protected area in Peru. *Mountain Research and Development*, *38*(3), 192–202. https://doi.org/10.1659/MRD-JOURNAL-D-17-00090.1

Colloff, M. J., Martín-López, B., Lavorel, S., Locatelli, B., Gorddard, R., Longaretti, P. Y., Walters, G., van Kerkhoff, L., Wyborn, C., Coreau, A., Wise, R. M., Dunlop, M., Degeorges, P., Grantham, H., Overton, I. C., Williams, R. D., Doherty, M. D., Capon, T., Sanderson, T., & Murphy, H. T. (2017). An integrative research framework for enabling transformative adaptation. *Environmental Science and Policy*, *68*, 87–96. https://doi.org/10.1016/j.envsci.2016.11.007

Dang, K. B., Nguyen, T. T., Ngo, H. H., Burkhard, B., Müller, F., Dang, V. B., Nguyen, H., Ngo, V. L., & Pham, T. P. N. (2021). Integrated methods and scenarios for assessment of sand dunes ecosystem services. *Journal of Environmental Management*, *289*, 112485. https://doi.org/10.1016/j.jenvman.2021.112485

De Luca, C., Langemeyer, J., Vaňo, S., Baró, F., & Andersson, E. (2021). Adaptive resilience of and through urban ecosystem services: A transdisciplinary approach to sustainability in Barcelona. *Ecology and Society*, *26*(4), 38. https://doi.org/10.5751/ES-12535-260438

Do, T. H., Vu, T. P., Catacutan, D., & Nguyen, V. T. (2021). Governing landscapes for ecosystem services: A participatory land-use scenario development in the northwest montane region of Vietnam. *Environmental Management*, *68*(5), 665–682. https://doi.org/10.1007/s00267-020-01378-2

Dou, Y., Zagaria, C., O'Connor, L., Thuiller, W., & Verburg, P. H. (2023). Using the nature futures framework as a lens for developing plural land use scenarios for Europe for 2050. *Global Environmental Change*, *83*, 102766. https://doi.org/10.1016/j.gloenvcha.2023.102766

Duguma, D. W., Law, E., Shumi, G., Schultner, J., Abson, D. J., & Fischer, J. (2024). Land use intensification causes the spatial contraction of woody-plant based ecosystem services in southwestern Ethiopia. *Communications Earth & Environment*, *5*(1), 263. https://doi.org/10.1038/s43247-024-01435-2

Durán, A. P., Kuiper, J. J., Aguiar, A. P. D., Cheung, W. W. L., Diaw, M. C., Halouani, G., Hashimoto, S., Gasalla, M. A., Peterson, G. D., Schoolenberg, M. A., Abbasov, R., Acosta, L. A., Armenteras, D., Davila, F., Denboba, M. A., Harrison, P. A., Harhash, K. A., Karlsson-Vinkhuyzen, S., Kim, H. J., … Pereira, L. M. (2023). Bringing the nature futures framework to life: Creating a set of illustrative narratives of nature futures. *Sustainability Science*. https://doi.org/10.1007/s11625-023-01316-1

Hallberg-Sramek, I., Nordström, E. M., Priebe, J., Reimerson, E., Mårald, E., & Nordin, A. (2023). Combining scientific and local knowledge improves evaluating future scenarios of forest ecosystem services. *Ecosystem Services*, *60*, 101512. https://doi.org/10.1016/j.ecoser.2023.101512

Jacobs, B., Boronyak, L., Mitchell, P., Vandenberg, M., & Batten, B. (2018). Towards a climate change adaptation strategy for national parks: Adaptive management pathways under dynamic risk. *Environmental Science and Policy*, *89*, 206–215. https://doi.org/10.1016/j.envsci.2018.08.001

Jorda-Capdevila, D., Rodríguez-Labajos, B., & Bardina, M. (2016). An integrative modelling approach for linking environmental flow management, ecosystem service provision and inter-stakeholder conflict. *Environmental Modelling and Software*, *79*, 22–34. https://doi.org/10.1016/j.envsoft.2016.01.007

Kabaya, K., Hashimoto, S., Fukuyo, N., Uetake, T., & Takeuchi, K. (2019). Investigating future ecosystem services through participatory scenario building and spatial ecological–economic modelling. *Sustainability Science*, *14*(1), 77–88. https://doi.org/10.1007/s11625-018-0590-1

Karner, K., Cord, A. F., Hagemann, N., Hernandez-Mora, N., Holzkämper, A., Jeangros, B., Lienhoop, N., Nitsch, H., Rivas, D., Schmid, E., Schulp, C. J. E., Strauch, M., van der Zanden, E. H., Volk, M., Willaarts, B., Zarrineh, N., & Schönhart, M. (2019). Developing stakeholder-driven scenarios on land sharing and land sparing – Insights from five European case studies. *Journal of Environmental Management*, *241*, 488–500. https://doi.org/10.1016/j.jenvman.2019.03.050

Karner, K., Mitter, H., Sinabell, F., & Schönhart, M. (2024). Participatory development of shared socioeconomic pathways for Austria's agriculture and food systems. *Land Use Policy*, *142*, 107183. https://doi.org/10.1016/j.landusepol.2024.107183

Koo, H., Kleemann, J., & Fürst, C. (2018). Land use scenario modeling based on local knowledge for the provision of ecosystem services in northern Ghana. *Land*, *7*(2), 59. https://doi.org/10.3390/land7020059

Larondelle, N., Frantzeskaki, N., & Haase, D. (2016). Mapping transition potential with stakeholder- and policy-driven scenarios in Rotterdam City. *Ecological Indicators*, *70*, 630–643. https://doi.org/10.1016/j.ecolind.2016.02.028

Malinga, R., Gordon, L. J., Lindborg, R., & Jewitt, G. (2013). Using participatory scenario planning to identify ecosystem services in changing landscapes. *Ecology and Society*, *18*(4), art10. https://doi.org/10.5751/ES-05494-180410

Martínez-Sastre, R., Ravera, F., González, J. A., López Santiago, C., Bidegain, I., & Munda, G. (2017). Mediterranean landscapes under change: Combining social multicriteria evaluation and the ecosystem services framework for land use planning. *Land Use Policy*, *67*, 472–486. https://doi.org/10.1016/j.landusepol.2017.06.001

Pace, L. A., Saritas, O., & Deidun, A. (2023). Exploring future research and innovation directions for a sustainable blue economy. *Marine Policy*, *148*, 105433. https://doi.org/10.1016/j.marpol.2022.105433

Palomo, I., Martín-López, B., López-Santiago, C., & Montes, C. (2011). Participatory scenario planning for protected areas management under the ecosystem services framework: The Doñana social-ecological system in Southwestern Spain. *Ecology and Society*, *16*(1), 33. https://www.jstor.org/stable/26268839

Reed, J., Chervier, C., Borah, J. R., Gumbo, D., Moombe, K. B., Mbanga, T. M., O'Connor, A., Siangulube, F., Yanou, M., & Sunderland, T. (2023). Co-producing theory of change to operationalize integrated landscape approaches. *Sustainability Science*, *18*(2), 839–855. https://doi.org/10.1007/s11625-022-01190-3

Richards, D., Herzig, A., Abbott, M., Ausseil, A. G., Guo, J., Sood, A., & Lavorel, S. (2023). Diverse contributions of nature to climate change adaptation in an upland landscape. *Ecosystems and People*, *19*(1), 2225647. https://doi.org/10.1080/26395916.2023.2225647

Ruiz, I., Pompeu, J., Ruano, A., Franco, P., Balbi, S., & Sanz, M. J. (2023). Combined artificial intelligence, sustainable land management, and stakeholder engagement for integrated landscape management in Mediterranean watersheds. *Environmental Science and Policy*, *145*, 217–227. https://doi.org/10.1016/j.envsci.2023.04.011

Saarikoski, H., Mustajoki, J., Hjerppe, T., & Aapala, K. (2019). Participatory multi-criteria decision analysis in valuing peatland ecosystem services—Trade-offs related to peat extraction vs. pristine peatlands in Southern Finland. *Ecological Economics*, *162*, 17–28. https://doi.org/10.1016/j.ecolecon.2019.04.010

Schneider, F., Feurer, M., Lundsgaard-Hansen, L. M., Myint, W., Nuam, C. D., Nydegger, K., Oberlack, C., Nwe Nwe Tun, Z., Aung Myin Tun, J. G., & Messerli, P. (2020). Sustainable development under competing claims on land: Three pathways between land-use changes, ecosystem services and human well-being. *European Journal of Development Research*, *32*(2), 316–337. https://doi.org/10.1057/s41287-020-00268-x

van Oijstaeijen, W., Silva, M. F. e., Back, P., Collins, A., Verheyen, K., de Beelde, R., Cools, J., & van Passel, S. (2023). The nature smart cities business model: A rapid decision-support and scenario analysis tool to reveal the multi-benefits of green infrastructure investments. *Urban Forestry & Urban Greening*, *84*, 127923. https://doi.org/10.1016/j.ufug.2023.127923

Vannier, C., Bierry, A., Longaretti, P. Y., Nettier, B., Cordonnier, T., Chauvin, C., Bertrand, N., Quétier, F., Lasseur, R., & Lavorel, S. (2019). Co-constructing future land-use scenarios for the Grenoble region, France. *Landscape and Urban Planning*, *190*, 103614. https://doi.org/10.1016/j.landurbplan.2019.103614

UK studies for scoping review

Balfour, N. J., Durrant, R., Ely, A., & Sandom, C. J. (2021). People, nature and large herbivores in a shared landscape: A mixed-method study of the ecological and social outcomes from agriculture and conservation. *People and Nature*, *3*(2), 418–430. https://doi.org/10.1002/pan3.10182

Balmford, A., Fisher, B., Green, R. E., Naidoo, R., Strassburg, B., Turner, R. K., & Rodrigues, A. S. L. (2011). Bringing ecosystem services into the real world: An operational framework for assessing the economic consequences of losing wild nature. *Environmental and Resource Economics*, *48*(2), 161–175. https://doi.org/10.1007/s10640-010-9413-2

Benton, T., Curry, A., Fredenburgh, J., Macmillan, T., Bridle, S., Bellamy, A. S., Kepinski, S., & Ward, N. (2023b). *What could the UK agri-food system look like in 2050?* Report from the AFN Network+. https://www.agrifood4netzero.net/wp-content/uploads/2024/04/UK-agri-food-system-scenarios.pdf

Burdon, D., Potts, T., Barnard, S., Boyes, S. J., & Lannin, A. (2022). Linking natural capital, benefits and beneficiaries: The role of participatory mapping and logic chains for community engagement. *Environmental Science and Policy*, *134*, 85–99. https://doi.org/10.1016/j.envsci.2022.04.003

Eastwood, A., Lorenzo-Arribas, A., Fischer, A., MacLean, L., Hague, A., Juarez-Bourke, A., Herrett, S., Byg, A., Marshall, K., Pakeman, R., Donaldson-Selby, G., & Hester, A. (2024). Exploring the impacts of woodland management on ecosystem services–A deliberative method. *Ecosystems and People*, *20*(1), 2322638. https://doi.org/10.1080/26395916.2024.2322638

Finch, T., Bradbury, R. B., Bradfer-Lawrence, T., Buchanan, G. M., Copping, J. P., Massimino, D., Smith, P., Peach, W. J., & Field, R. H. (2023). Spatially targeted nature-based solutions can mitigate climate change and nature loss but require a systems approach. *One Earth*, *6*(10), 1350–1374. https://doi.org/10.1016/j.oneear.2023.09.005

Finch, T., Gillings, S., Green, R. E., Massimino, D., Peach, W. J., & Balmford, A. (2019). Bird conservation and the land sharing-sparing continuum in farmland-dominated landscapes of lowland England. *Conservation Biology*, *33*(5), 1045–1055. https://doi.org/10.1111/cobi.13316

Garnett, K., Delgado, J., Lickorish, F., Shaw, H., Rathe, A., Chatterton, J., Prpich, G., & Pollard, S. J. T. (2014). *Plausible future scenarios for the UK Food and Feed System 2015 & 2035*. Food and Feed System Scenarios.

Harmáčková, Z. v., Pedde, S., Bullock, J. M., Dellaccio, O., Dicks, J., Linney, G., Merkle, M., Rounsevell, M. D. A., Stenning, J., & Harrison, P. A. (2022). Improving regional applicability of the UK shared socioeconomic pathways through iterative participatory co-design. *Climate Risk Management*, *37*, e100452. https://doi.org/10.1016/j.crm.2022.100452

Holman, I. P., Harrison, P. A., & Metzger, M. J. (2016). Cross-sectoral impacts of climate and socio-economic change in Scotland: Implications for adaptation policy. *Regional Environmental Change*, *16*(1), 97–109. https://doi.org/10.1007/s10113-014-0679-8

Holman, I. P., Rounsevell, M. D. A., Cojacaru, G., Shackley, S., McLachlan, C., Audsley, E., Berry, P. M., Fontaine, C., Harrison, P. A., Henriques, C., Mokrech, M., Nicholls, R. J., Pearn, K. R., & Richards, J. A. (2008). The concepts and development of a participatory regional integrated assessment tool. *Climatic Change*, *90*(1–2), 5–30. https://doi.org/10.1007/s10584-008-9453-6

Jones, S. M., Smith, A. C., Leach, N., Henrys, P., Atkinson, P. M., & Harrison, P. A. (2023b). Pathways to achieving nature-positive and carbon–neutral land use and food systems in Wales. *Regional Environmental Change*, *23*(1), 37. https://doi.org/10.1007/s10113-023-02041-2

Kumar, V., Rouquette, J. R., & Lerner, D. N. (2013). Integrated modelling for sustainability appraisal of urban river corridors: Going beyond compartmentalised thinking. *Water Research*, *47*(20), 7221–7234. https://doi.org/10.1016/j.watres.2013.10.034

Larkin, J., Sheridan, H., Finn, J. A., Denniston, H., & Ó hUallacháin, D. (2019). Semi-natural habitats and ecological focus areas on cereal, beef and dairy farms in Ireland. *Land Use Policy*, *88*, 104096. https://doi.org/10.1016/j.landusepol.2019.104096

Partidário, M. R., Sheate, W. R., Bina, O., Byron, H., & Augusto, B. (2009). Sustainability assessment for agriculture scenarios in Europe's mountain areas: Lessons from six study areas. *Environmental Management*, *43*(1), 144–165. https://doi.org/10.1007/s00267-008-9206-3

Sheate, W. R., do Partidário, M. R., Byron, H., Bina, O., & Dagg, S. (2008). Sustainability assessment of future scenarios: Methodology and application to mountain areas of Europe. *Environmental Management*, *41*(2), 282–299. https://doi.org/10.1007/s00267-007-9051-9

Smith, A. C., Harrison, P. A., Leach, N. J., Godfray, H. C. J., Hall, J. W., Jones, S. M., Gall, S. S., & Obersteiner, M. (2023b). Sustainable pathways towards climate and biodiversity goals in the UK: The importance of managing land-use synergies and trade-offs. *Sustainability Science*, *18*(1), 521–538. https://doi.org/10.1007/s11625-022-01242-8

Southern, A., Lovett, A., O'Riordan, T., & Watkinson, A. (2011). Sustainable landscape governance: Lessons from a catchment based study in whole landscape design. *Landscape and Urban Planning*, *101*(2), 179–189. https://doi.org/10.1016/j.landurbplan.2011.02.010

Thomas, A., Cosby, B. J., Gooday, R., Lyons, H., Siriwardena, G., Kettel, E., Matthews, R., Beauchamp, K., Petr, M., & Emmett, B. A. (2021). Rapid adaptive modelling for policy support towards achieving sustainable development goals: Brexit and the livestock sector in Wales. *Environmental Science & Policy*, *125*, 21–31. https://doi.org/10.1016/j.envsci.2021.08.009

Yumashev, D., Janes-Bassett, V., Redhead, J. W., Rowe, E. C., & Davies, J. (2022). Terrestrial carbon sequestration under future climate, nutrient and land use change and management scenarios: A national-scale UK case study. *Environmental Research Letters*, *17*(11), 114054. https://doi.org/10.1088/1748-9326/aca037

References for protected area case study

Barnes, A. E., Davies, J. G., Martay, B., Boersch-Supan, P. H., Harris, S. J., Noble, D. G., Pearce-Higgins, J. W., & Robinson, R. A. (2023). Rare and declining bird species benefit most from designating protected areas for conservation in the UK. *Nature Ecology & Evolution*, *7*(1), 92–101.

Border, J. A., Newson, S. E., White, D. C. J., & Gillings, S. (2017). Predicting the likely impact of urbanisation on bat populations using citizen science data, a case study for Norfolk, UK. *Landscape and Urban Planning*, *162*, 44–55.

Brighton, C. H., Massimino, D., Boersch-Supan, P., Barnes, A. E., Martay, B., Bowler, D. E., Hoskins, H. M. J., & Pearce-Higgins, J. W. (2024). The benefits of protected areas for bird population trends may depend on their condition. *Biological Conservation*, *292*, 110553.

Convention on Biological Diversity (CBD). (2020). *Zero draft of the post-2020 global biodiversity framework* (CBD/WG2020/2/3). https://www.cbd.int/doc/c/efb0/1f84/a892b98d2982a829962b6371/wg2020-02-03-en.pdf

Massimino, D., Baillie, S. R., Balmer, D. E., Bashford, R. I., Gregory, R. D., Harris, S. J., Heywood, J. J. N., Kelly, L. A., Noble, D. G., Pearce-Higgins, J. W., Raven, M. J., Risely, K., Woodcock, P., Wotton, S. R., & Gillings, S. (2025). The breeding bird survey of the United Kingdom. *Global Ecology and Biogeography*, *34*(1), e13943.

Sutherland, W. J., Taylor, N. G., MacFarlane, D., Amano, T., Christie, A. P., Dicks, L. V., Lemasson, A. J., Littlewood, N. A., Martin, P. A., Ockendon, N., Petrovan, S. O., Robertson, R. J., Rocha, R., Shackelford, G. E., Smith, R. K., Tyler, E. H. M., & Wordley, C. F. R. (2019). Building a tool to overcome barriers in research-implementation spaces: The conservation evidence database. *Biological Conservation*, *238*, 108199.

UNEP/CBD. (2022). *Decision adopted by the conference of the parties to the convention on biological diversity 15/4. Kunming-Montreal Global Biodiversity Framework* (CBD/COP/DEC/15/4 19). https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf

WWF. (2020). In R. E. A. Almond, M. Grooten, & T. Petersen (Eds.), *Living planet report 2020. Bending the curve of biodiversity loss*. WWF.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Coding to policy-relevant questions.

Table S2. Coding to design decisions.

Table S3. Full list of examples from studies in review for each design decision.

Table S4. Design decisions co-occurrence table.

How to cite this article: Lazurko, A., Sinclair, S., Border, J. A., Bowler, D. E., Morgan, W. H., Pearce-Higgins, J. W., Woodcock, P., & Isaac, N. J. B. (2026). Which biodiversity futures? Towards coherent design choices for scenarios exploring policy-relevant questions. *People and Nature*, *00*, 1–22. https://doi.org/10.1002/pan3.70388