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Making palaeoclimatology research policy-relevant: Insights and experience from the DECADAL Project

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ABSTRACT: Quaternary palaeoclimatology uniquely provides insights and new evidence about climate variability trends and extremes prior to the instrumental record; yet, its knowledge is rarely integrated into governmental decision-making. This opinion piece shares lessons and experience from the UKRI-funded DECADAL project, which bridges palaeoclimate science and policy through co-production with UK climate services and policy institutions. The views expressed represent a joint perspective of the academic and non-academic actors involved in the project, highlighting the challenges that we faced and the solutions that we adopted. We found that an iterative collaboration through aligning research questions, outputs and formats with user needs builds trust, increases relevance and creates pathways for long-term policy uptake. DECADAL demonstrates that engaging with relevant policy and other end-user groups does not compromise scientific excellence; rather, it drives methodological innovation and rigour, fosters creativity and produces high-impact, original publications that also have relevance beyond an academic audience. We argue that embedding policy engagement should be viewed as a collective community endeavour rather than the effort of an individual or research team. By embracing co-production, palaeo-scientists can strengthen the societal value of their research, open new avenues for innovation and collaboration, and collectively shape climate-informed decision-making. © 2026 The Author(s). *Journal of Quaternary Science* Published by John Wiley & Sons Ltd.

KEYWORDS: co-production; palaeoclimatology; policy impact

Introduction

Palaeoclimatology extends our understanding of climate prior to the instrumental period (~1850 CE to present), capturing low- and high-frequency variability, extremes, trends and Earth-system responses to climate changes likely comparable in magnitude to those projected for the future (Harrison et al., 2025; Kageyama et al., 2024). The Intergovernmental Panel for Climate Change (IPCC) has progressively incorporated palaeoclimate evidence into its assessments, reflecting its growing relevance for climate policy. The IPCC's Forth Assessment Report (AR4) included a dedicated palaeoclimate chapter synthesising past climate states and variability (Jansen et al., 2007). AR5 primarily used palaeoclimate evidence to contextualise recent climate change within the framework of past natural variability (Masson-Delmonte et al., 2014). In the AR6, palaeoclimate evidence was no longer presented as a distinct chapter, but distributed across multiple Working Group I (WGI) chapters. It was more directly applied to constrain key projections, such as equilibrium climate sensitivity and the assessment of climate states warmer than the pre-industrial period (IPCC, 2021). Palaeoclimate

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evidence was also integrated in the contents of the WGI Summary for Policy Makers, which highlighted findings of direct relevance to decision-makers (Kaufman and Masson-Delmotte, 2024). A similar approach is anticipated for AR7 (2023–2029), which provides a timely opportunity to stimulate new palaeoclimate research explicitly orientated towards policy-relevant questions.

In parallel, the climate policy landscape increasingly relies on climate services (i.e., the provision of climate information tailored to user needs) as a mechanism to support adaptation, mitigation and risk management (WMO, 2023; Jacob et al., 2025). National meteorological and hydrological services, international organisations and public institutions such as government departments now act as liaisons between climate science and decision-makers (Golding et al., 2025; Hewitt et al., 2020). However, palaeoclimate research has largely been excluded from the core of these services, often being treated as supplemental or separate (similar to the early iterations of the IPCC) rather than integral to established workflows (Bruno Soares et al., 2018).

A potential pathway for embedding palaeoclimate outputs into policy and decision-making frameworks is co-production. Co-production refers to sustained, iterative collaboration between scientists and users in which research questions, outputs and modes of delivery are jointly shaped (Meadow et al., 2015). Here, we use the UK Research and Innovation-funded project 'DECADAL: Rethinking Palaeoclimatology for Society' to exemplify this approach (www.palaeodecadal.org). DECADAL's scientific research focuses on reconstructing and understanding climate variability on annual to decadal time scales during the Holocene, while developing co-production with climate services and decision-making teams in the UK Government to help frame the research outputs in ways that are directly responsive to future-oriented climate questions. In this opinion piece, we (i) present a Theory of Change linking Quaternary palaeoclimate research to climate-service and policy needs, (ii) identify common challenges that limit uptake of palaeoclimate research and (iii) propose transferable recommendations for embedding co-production in future palaeoclimate programmes.

A Theory of Change for palaeoclimate research impact

DECADAL is underpinned by a Theory of Change (ToC) that articulates how co-produced palaeoclimate research can contribute to longer-term policy-relevant outcomes after the project lifetime (Boyall, 2025). A ToC is a framework widely used in applied research and public policy to explain how a programme's resources and activities are expected to contribute to specific outcomes and longer-term results through explicit assumptions and intermediate steps. ToCs are often diagrams (Fig. 1) accompanied by a narrative; they provide a conceptual framework for monitoring (tracking implementation), evaluating (assessing results and causul links) and learning (reflecting on and adapting based on evidence), by making causal logic testable and clarifying where evidence is needed. The ToC developed for DECADAL links palaeoclimate research activities to the decision-relevant outcomes that we were aiming to achieve (Boyall, 2025), and it guided the project's work. We present it here to provide a transferable example for other research projects seeking to strengthen policy relevance.

The central assumption of the DECADAL ToC is that there is sufficient scientific, institutional and policy ambition to strengthen decadal-scale future climate predictions and to link policy processes to these predictions (Done et al., 2021). Within this context, palaeoclimate research is positioned as a key contributor by extending the evidence base for decadal climate variability, extremes and uncertainty prior to the instrumental record (Boyall, 2025).

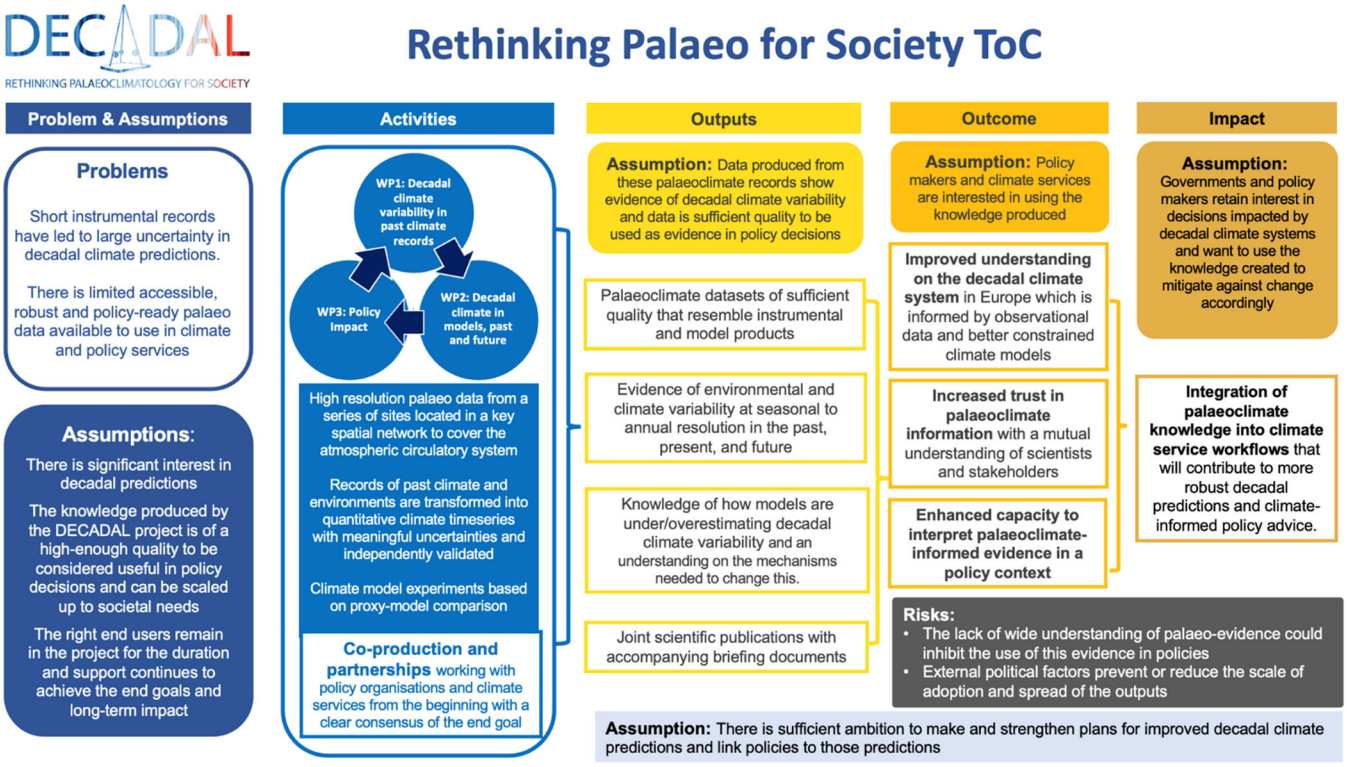

Figure 1. The Theory of Change for the DECADAL project. This diagram summarises the flow of knowledge transfer from activities through to the final long-term impact whilst highlighting the assumptions made and potential risks. [Color figure can be viewed at wileyonlinelibrary.com]

Activities: Co-produced proxy and model-based research; collaboration with climate service scientists; policy literacy training through secondments; and sustained engagement.

Outputs: Palaeoclimate data sets aligned with instrumental and model products; joint publications; and policy briefings.

Outcomes: increased trust in palaeoclimate evidence; improved usability of outputs and mutual understanding between scientists and policy advisers; and enhanced capacity to interpret palaeoclimate-informed evidence in a policy context.

Longer-term impacts: integration of palaeoclimate knowledge into climate service workflows, model evaluation and uncertainty assessment, which should lead to more robust climate advice.

The ToC also explicitly recognises risks, including shifting policy priorities, institutional turnover, lack of interest and persistent concerns about palaeoclimate uncertainty. By acknowledging these risks, DECADAL treats impact as an adaptive and iterative process, reinforcing the view that policy relevance must be actively cultivated over time rather than assumed (Boyall, 2025).

Impact challenges and DECADAL approach

From its design in 2021 through its implementation (2022–2026), the DECADAL project has encountered several challenges in its process towards impact through research (Table 1).

1. Co-production of research for policy

Identifying relevant end users and interested parties, and engaging them in a co-production process, can be both challenging and time-consuming. It requires a wide range of communication skills, sustained effort to understand different institutional landscapes, identify individuals with relevant roles and interests, and build relationships based on trust and mutual benefit. Non-academic partners do not often have the time to read the literature or search for evidence beyond that provided through routine pathways, so collaboration requires scientists to make the first move. Selecting the right organisations and individuals to collaborate with is critical and needs to be aligned with clearly defined impact priorities. Effective policy engagement requires researchers to first identify their target policy level (local, national or intergovernmental), and then to find the most relevant organisations or teams, define the most appropriate policy areas for their expertise and honestly assess their own capacities and strengths to engage.

DECADAL approach

DECADAL is innovative in developing seasonal-sensitive, calibrated, continuous climate reconstructions at annual resolution for the Holocene period (the last 11 700 years before 1950 CE) based on physical and biological proxies preserved in lacustrine records, which are combined with climate modelling. While the novel reconstructions are targeted at deciphering the actual past evolution of climate, climate modelling produces past states that are consistent with the physical equations and mechanisms that rule the behaviour of the climate subsystems, providing the link with current and future climate. According to this scientific plan, DECADAL explored three potential policy-relevant topics: (i) disaster risk reduction, utilising long-term climate records and palaeoclimate evidence to capture rare extremes and define worst-case scenarios and compound risks; (ii) nature-based solutions for aquatic ecosystems, where long-term biological records identify resilience limits, recovery times, environmental thresholds and realistic time scales for benefits; and (iii) climate services, with palaeoclimate providing extended climate observations to evaluate decadal variability, constrain uncertainty and disentangle internal and external forcing for accurate predictions, which is crucial to sectors affected by multi-annual climate variability such as water management, energy and agriculture.

A key early challenge was finding suitable government contacts with capacity to engage. As DECADAL's impact was targeted at a national (UK) level with potential indirect intergovernmental influence, we looked for key organisations working on the three topics above. We finally engaged with the Department for Environment Food and Rural Affairs

Table 1. Lessons learned from DECADAL to promote longer-term impact through palaeoclimate research.

Lesson	Key actions
Explicitly articulate a Theory of Change	Define assumptions, goals, risks and expected intermediate outcomes from the research; emphasise that trust, usability of research findings and shared understanding are legitimate outcomes even if immediate impact is not measurable.
Embed co-production from the start	Collaborate with policy-facing institutions early and consistently throughout and after a project; co-produce research questions, outputs and delivery mechanisms while retaining scientific autonomy.
Build trust through repeated interaction	Establish long-term relationships via periodic meetings, informal exchanges, joint events and secondments to policy institutions.
Reflect on and adapt to poor engagement	Identify institutional, cultural and policy barriers that might prevent engagement between research and end users; treat impact and engagement as an iterative and adaptive process rather than linear.
Align with climate service frameworks	Work with boundary or intermediary organisations (e.g., national meteorological offices and/or the World Meteorological Organization) to ensure that palaeoclimate outputs can be integrated into established climate service structures.
Make palaeoclimate data look familiar	Translate palaeoclimate data sets into formats similar to instrumental or re-analysis data; provide clear metadata, uncertainty representation and ensembles of reconstructions.
Develop use cases even if impact is not yet quantifiable	Conduct pilot studies demonstrating relevance for policy-relevant issues (e.g., extreme events, decadal variability and climate sensitivity) to show practical value.
Train scientists and policy advisers	Provide training for scientists in policy processes and for policy advisers in palaeoclimate basics; organise workshops and joint sessions to enhance shared understanding.
Disseminate and normalise impact-oriented thinking	Share experiences, surveys, best practices and talks at conferences and seminars to foster a community culture valuing co-production and policy engagement.

(Defra), the Department for Energy Security and Net Zero (DESNZ), the Foreign, Commonwealth and Development Office (FCDO), Natural England, the Royal Society, the Met Office and the World Meteorological Organization. The foundations of the co-production with our partners were inspired by UK examples where palaeoenvironmental science has supported environmental conservation and adaptation decisions (e.g., Davies et al., 2014). Where DECADAL differs from the former is in the embedding of co-production in a palaeoclimate context to deliver policy-relevant research. However, given that routes between palaeoclimate, climate services and policy institutions are not yet routinely established, we largely had to build the relationships and pathways for uptake from scratch. Initial contact with policy and climate-service partners began during proposal development (well before the formal start of the funded project) and continued throughout the early stages of the project. We initiated conversations by email, introducing the project concept, outlining what DECADAL could offer and inviting discussion about potential mutual benefits. These exchanges led to follow-up meetings that refined DECADAL's framing, shared priorities and decision-relevant outputs. Relationships built progressively through personal networks and repeated interactions, though time-consuming, established trust and mutual expectations.

2. Mismatched temporal scales and workflows

Policy and climate service workflows are oriented towards near- and mid-term decision horizons (Dunstone et al., 2022; O'Kane et al., 2023). Most decision-support frameworks emphasise seasonal-to-decadal outlooks, risk assessments and forward-looking scenarios, all of which rely primarily on instrumental observations and model predictions. Palaeoclimate research has traditionally emphasised low-frequency variability (e.g., multi-decadal to millennial scales) over much longer time horizons (e.g., thousands and hundreds of thousands of years) and retrospective process understanding. Whilst this approach offers important insights to system responses to drivers and resilience behaviours relevant to future climate change, the temporal resolution and objectives are often misaligned with policy priorities (Allen et al., 2025; Harrison et al., 2025; Kageyama et al., 2024).

DECADAL approach

To address the disconnect between palaeoclimate time scales and policy-relevant decision horizons, DECADAL adopts a co-produced, multidisciplinary methodology. This combines a synthesis of regionally coherent, quality-controlled high-resolution palaeoclimate compilations, recent methodological innovations such as Bayesian inference and the use of machine learning, climate modelling and climate service expertise. We focus on decadal climate variability and seasonal extremes over the past thousand years to help improve decadal climate predictions, so they can better inform user decisions as they become more widely used (Done et al., 2021; Hermanson et al., 2022; Kushnir et al., 2019). Research questions in DECADAL were iteratively co-designed with partners to keep methods and outputs familiar and aligned with climate service needs (e.g., application of state-of-the-art time-series analysis used in climatology to palaeoclimate data). Discussions often revealed practical evidence gaps, prompting the science team to reframe analyses or adapt outputs to meet end users' needs while maintaining rigour. Key outcomes include the development of SCUBIDO (Simulating Climate Using Bayesian Inference with proxy Data Observations, Boyall et al., 2025), a model that enables annual to seasonal climate reconstructions from proxy-records with fully quantified uncertainties, which address the critical need for connecting the palaeo- and instrumental record. This was applied to contextualise recent multi-decadal trends, such as longer and warmer summers (Martin-Puertas et al., 2025) and the amplified warming over Europe (Al-Yaari et al., 2026), and to provide observationally constrained future estimates under different emission scenarios by combining model projections with palaeodata.

3. Enabling multidisciplinarity

For palaeoclimate knowledge to contribute effectively to policy-relevant analyses, it must be integrated with other forms of evidence used in multidisciplinary climate assessments. Palaeoclimate information is often distributed as heterogeneous proxy records with varying temporal resolutions, spatial coverage and age uncertainty structures, posing challenges for integration with instrumental observations, model outputs and impact data sets.

DECADAL approach

A core goal of the project was to make palaeoclimate outputs as compatible as possible with instrumental and model-based data sets within a consistent statistical framework, aligning outputs with formats that end users are familiar with. We developed a statistical model to transform proxy records into climate time series with quantitative uncertainties based on iterative model runs (Boyall, 2025). This allows probabilistic past observations for model evaluation (e.g., likelihood and persistence of unusual, extreme climate events) and enables data-model comparison using formal statistical metrics across time scales, aligning palaeoclimate products with the standards used in climate services, risk assessment and policy advice. The adoption of FAIR (Findable, Accessible, Interoperable, and Reusable) data principles (Jacobsen et al., 2024; Wilkinson et al., 2016) alongside the translation of proxy records into more standardised and user-orientated formats offers a practical pathway to help integrate palaeodata into multidisciplinary climate services and modelling workflows.

In parallel, sustained relationship building through workshops and training sessions has helped develop a shared understanding of decision-relevant questions and increased the visibility of palaeoclimate expertise. Importantly, we found that partners often needed to see initial results to recognise their relevance and to envisage how outputs could be used. For example, once the first climate reconstructions from DECADAL were produced (and their value demonstrated; Boyall, 2025), engagement with the Met Office increased markedly; interactions evolved from mainly informative and advisory exchanges to active scientific collaboration, and the project is now jointly developing several research studies with these partners focussed on past climate constraints and characterisation of high-impact low-probability events (unpublished). We expect this collaboration to lead to multidisciplinary assessments, briefs or reports to inform climate policy that explicitly incorporates palaeoclimate evidence.

The dissemination of novel scientific findings in an accessible format, for example, through articles in trusted platforms such as The Conversation (Hernandez and Martin-Puertas, 2026), also helps increase the visibility of palaeoclimate science and its implications for climate prediction and policy. Such formats are widely read within the climate services community because they are relatively quick, available in different languages and easy to engage with, and they help readers identify appropriate experts to contact for further information.

4. Impact pathways

Policy relevance is rarely articulated explicitly in palaeoclimate research design. A common expectation is that relevance will emerge over time through peer-reviewed publication, subsequent synthesis in assessment reports such as the IPCC and longer-term knowledge accumulation (i.e., a linear, long-term pipeline from research to policy impact). While IPCC uptake is valuable and influential, reliance on this route does not align well with the accountability requirements and decision timelines of policy institutions and funders. As a result, even highly relevant palaeoclimate insights often remain difficult to translate into timely, demonstrable or traceable impact (Allen et al., 2025).

DECADAL approach

DECADAL complements these established linear routes from research to eventual impact through sustained sharing of research outputs in regular meetings, newsletters and regular informal exchanges. This creates multiple pathways for research application, including service-facing outputs and shared interpretations of uncertainties in forms that partners can use. This approach also helps to broaden where it is that 'impact' can arise, recognising that usability depends not only on academic visibility but also on accessibility, format and relationships. Together, these practices have strengthened our potential for demonstrable impact, and DECADAL has already established a trust-based network, even though formal policy impact, such as that defined by frameworks like the Research Excellence Framework (REF 2029, 2025), has not been achieved yet.

5. Academic and community barriers

Academic career structures typically prioritise publication output over engagement or impact, providing little incentive for researchers to invest time in developing policy-relevant relationships (Pearson, 2024). Poor knowledge of the policy advising system and the policy cycle may also prevent palaeoclimate scientists from pursuing policy engagement or from recognising when and how their expertise could be effectively used. Concerns from the palaeoclimate community about uncertainty in the quantification and robustness of the climate reconstructions, misinterpretation of data and limitations on research autonomy may also pose barriers for researchers to apply their expertise to policy advising.

DECADAL approach

We immersed palaeoclimate scientists in policy environments through work shadowing and secondments at DESNZ, Defra and FCDO; this was complemented by recurrent meetings and interviews (Boyall et al., 2026). These activities provided first-hand exposure to decision-making processes, built skills in framing evidence for non-specialist audiences and familiarised researchers with policy timelines. Shadowing and secondments were not always aligned to specific research themes; their value lay in general immersion in policy language, structures and culture, while expanding networks across government. In addition to these valuable learning experiences for palaeoclimate scientists, engagement through shadowing and secondments also offered those working in government policy areas equally valuable exposure to the research environment. Sustained interaction provided opportunities for policy advisers to become better-informed and active participants in the research process. The benefits of this two-way engagement and collaboration flow into establishing trust between research and policy practitioners and a recognition and understanding of domain expertise, which are both necessary for policy relevance and uptake of research outputs. Lessons from these experiences helped shape and prioritise DECADAL research towards societally relevant topics such as impacts of changes in ocean circulation, extreme events and nature-based solutions (Abrook et al., 2025, 2026; Al-Yaari et al., 2026; Lincoln et al., 2025; Martin-Puertas et al., 2025).

Embedding co-production in future palaeoclimate programmes

DECADAL illustrates that policy impact in palaeoclimate research emerges through incremental, relational and process-driven pathways. Trust, usability and shared understanding are foundational conditions for uptake of research into decision-making. The use of palaeoclimate as a source of evidence in policy is still in its infancy; thus, achieving direct policy change or the routine inclusion of palaeoclimate evidence in policy advice is a grand goal that would be achievable through sustained, coordinated effort across the palaeoclimate community to normalise co-production and policy literacy as integral components of palaeoclimate research. By collectively investing in shared relationships with climate services, aligning research outputs with policy-relevant frameworks and openly exchanging lessons learned, including failures and delays, we view this goal as achievable over the next decade, particularly as scientific communities, funders, academic institutions and governments increasingly recognise the importance of incorporating scientific evidence into decision-making.

Co-produced research projects will strengthen innovation, critical thinking and problem solving by integrating different types of expertise and evidence needs across communities. An important insight from the DECADAL project is that addressing policy relevance and engagement does not hinder research productivity. On the contrary, sustained interactions with relevant parties and end users demand state-of-the-art methodologies, rigorous analyses and high-quality outputs to maintain credibility and usefulness. This expectation encouraged the DECADAL team to uphold the highest scientific standards, resulting in research that is robust, reproducible and suitable for publication in high-impact journals (e.g., (Abrook et al., 2025; Al-Yaari et al., 2026; Boyall et al., 2025; Lincoln et al., 2025; Martin-Puertas et al., 2023, 2025)). Rather than being a distraction or constraint, our experience is that policy engagement can enhance scientific creativity, visibility and impact, establishing a mutually reinforcing cycle in which high-quality research strengthens credibility with relevant parties, and partner-driven challenges inspire novel scientific insights.

Co-production, however, requires additional effort to sustain engagement throughout the project, including the project design phase and extending well beyond the core scientific research. It was not always possible to convene the right mix of expertise at the right time (e.g., for project meetings), given differing institutional schedules, priorities and staff turnover in the policy partners. The co-production process has involved a steep learning curve for the whole DECADAL project team in navigating differences between academic research and policy approaches (Briley et al., 2015; Rosemartin et al., 2023). The challenges have reinforced the importance of patience and continuity, but we consider the investment in this approach worthwhile for the long-term relationships and shared understanding that it has built for the project (including all the project partners) and how this can filter into the palaeoclimate

community as a whole. We acknowledge that the co-production initiative here was enabled by dedicated financial support, and that many research systems continue to prioritise traditional outputs; encouragingly, however, there is growing recognition across funders and institutions of the value of engagement and impact through research.

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Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

Abrook, A.M., Inglis, G.N., Langdon, P.G., Bentley, M.R., Brauer, A. & Bull, I. (2026) Evaluating glycerol dialkyl glycerol tetraether (GDGT)-based reconstructions from varved lake sediments during the Holocene. *Biogeosciences*, 23, 1809–1832.

Abrook, A.M., Langdon, P.G., Inglis, G.N., Brauer, A., Lincoln, P. & Mayfield, R. et al. (2025) The role of summer temperature on aquatic insect diversity at multi-decadal scales within the Holocene. *Global Change Biology*, 31, e70366. Available from: https://doi.org/10.1111/gcb.70366

Allen, K.J., Gouramanis, C. & Sauchyn, D. (2025) Paleo-data is policy relevant: How do we better incorporate it in policy and decision making? *Global and Planetary Change*, 246, 104707. Available from: https://doi.org/10.1016/j.gloplacha.2025.104707

Al-Yaari, A., Swingedouw, D., Braconnot, P., Boyall, L., Lincoln, P., Marti, O. et al. (2026) Multi-centennial internal variability in the North Atlantic could drive additional warming over Europe. *Nature Communications*, 17, 2614. Available from: https://doi.org/10.1038/s41467-026-69209-2

Boyall, L. (2025) *A transdisciplinary investigation of the role of palaeoclimate in UK climate policy: a novel palaeolimnological journey to maximise policy impact*. Doctoral Thesis, Royal Holloway, University of London.

Boyall, L., Milner, A.M., Dodds, K. & MartinPuertas, C. (2026) Barriers and facilitators for using palaeoclimate evidence in UK climate decision making. *Geoscience Communication*, 9, 275–289. Available from: https://doi.org/10.5194/gc-9-275-2026

Boyall, L., Parnell, A.C., Lincoln, P., Ojala, A., Hernández, A. & Martin-Puertas, C. (2025) SCUBIDO: a Bayesian modelling approach to reconstruct palaeoclimate from multivariate lake sediment data. *Climate of the Past*, 21, 1465–1480. Available from: https://doi.org/10.5194/cp-21-1465-2025

Briley, L., Brown, D. & Kalafatis, S.E. (2015) Overcoming barriers during the co-production of climate information for decision-making. *Climate Risk Management, Boundary Organizations*, 9, 41–49. Available from: https://doi.org/10.1016/j.crm.2015.04.004

Bruno Soares, M., Alexander, M. & Dessai, S. (2018) Sectoral use of climate information in Europe: a synoptic overview. *Climate Services, Climate services in practice: what we learnt from EUPORIAS*, 9, 5–20. Available from: https://doi.org/10.1016/j.cliser.2017.06.001

Davies, A.L., Colombo, S. & Hanley, N. (2014) Improving the application of long-term ecology in conservation and land management. *Journal of Applied Ecology*, 51, 63–70. Available from: https://doi.org/10.1111/1365-2664.12163

Done, J.M., Morss, R.E., Lazrus, H., Towler, E., Tye, M.R., Ge, M. et al. (2021) Toward usable predictive climate information at decadal timescales. *One Earth*, 4, 1297–1309. Available from: https://doi.org/10.1016/j.oneear.2021.08.013

Dunstone, N., Lockwood, J., Solaraju-Murali, B., Reinhardt, K., Tsartsali, E.E., Athanasiadis, P.J. et al. (2022) Towards useful decadal climate services. *Bulletin of the American Meteorological Society*, 103, E1705–E1719. Available from: https://doi.org/10.1175/BAMS-D-21-0190.1

Golding, N., Lambkin, K., Wilson, L., Troch, R.D., Fischer, A.M. & Hygen, H.O. et al. (2025) Developing national frameworks for climate services: experiences, challenges and learnings from across Europe. *Climate Services*, 37, 100530. Available from: https://doi.org/10.1016/j.cliser.2024.100530

Harrison, S.P., Bartlein, P.J., Cruz-Silva, E., Haas, O., Jackson, S.T., Kaushal, N. et al. (2025) Paleoclimate perspectives on contemporary climate change. *Annual Review of Environment and Resources*, 50, 67–95. Available from: https://doi.org/10.1146/annurev-environ-112922-110121

Hermanson, L., Smith, D., Seabrook, M., Bilbao, R., Doblas-Reyes, F., Tourigny, E. et al. (2022) WMO global annual to decadal climate update: a prediction for 2021–25. *Bulletin of the American Meteorological Society*, 103, E1117–E1129. Available from: https://doi.org/10.1175/BAMS-D-20-0311.1

Hernandez, A. & Martin-Puertas, C. (2026) Doscientos dias de verano. *The Conversation*, 11 January. Available from: https://doi.org/10.64628/AAO.j44yccppr

Hewitt, C.D., Allis, E., Mason, S.J., Muth, M., Pulwarty, R., Shumake-Guillemot, J. et al. (2020) Making society climate resilient: international progress under the global framework for climate services. *Bulletin of the American Meteorological Society*, 101, E237–E252. Available from: https://doi.org/10.1175/BAMS-D-18-0211.1

IPCC. (2021) Climate change 2021: the physical science basis. In: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S. et al. (Eds.) *Contribution of working group I to the sixth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Jacob, D., Lera St. Clair, A., Mahon, R., Marsland, S., Ndebele Murisa, M., Buontempo, C. et al. (2025) Co-production of climate services: challenges and enablers. *Frontiers in Climate*, 7, 1507759. Available from: https://doi.org/10.3389/fclim.2025.1507759

Jacobsen, A., de Miranda Azevedo, R., Juty, N., Batista, D., Coles, S., Cornet, R. et al. (2020) FAIR principles: interpretations and implementation considerations. *Data Intelligence*, 2, 10–29. Available from: https://doi.org/10.1162/dint_r_00024

Jansen, E., Overpeck, J., Briffa, K.R., Duplessy, J.-C., Joos, F. & Masson-Delmotte, V. et al. (2007) Palaeoclimate. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M. & Averyt, K.B. et al. (Eds.) *Climate change 2007: the physical science basis, contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Kageyama, M., Braconnot, P., Chiessi, C.M., Rehfeld, K., Ait Brahim, Y., Dütsch, M. et al. (2024) Lessons from paleoclimates for recent and future climate change: opportunities and insights. *Frontiers in Climate*, 6, 1511997. Available from: https://doi.org/10.3389/fclim.2024.1511997

Kaufman, D. & Masson-Delmotte, V. (2024) Opinion: distribute paleoscience information across the next Intergovernmental Panel on Climate Change reports. *Climate of the Past*, 20, 2587–2594. Available from: https://doi.org/10.5194/cp-20-2587-2024

Kushnir, Y., Scaife, A.A., Arritt, R., Balsamo, G., Boer, G., Doblas-Reyes, F. et al. (2019) Towards operational predictions of the near-term climate. *Nature Climate Change*, 9, 94–101. Available from: https://doi.org/10.1038/s41558-018-0359-7

Lincoln, P., Tjallingii, R., Kosonen, E., Ojala, A., Abrook, A.M. & Martin-Puertas, C. (2025) Disruption of boreal lake circulation in response to mid-Holocene warmth; evidence from the varved sediments of Lake Nautajärvi, southern Finland. *Science of the Total*

Environment, 964, 178519. Available from: https://doi.org/10.1016/j.scitotenv.2025.178519

Martin-Puertas, C., Hernandez, A., Pardo-Igúzquiza, E., Boyall, L., Brierley, C., Jiang, Z. et al. (2023) Dampened predictable decadal North Atlantic climate fluctuations due to ice melting. *Nature Geoscience*, 16, 357–362. Available from: https://doi.org/10.1038/s41561-023-01145-y

Martin-Puertas, C., Boyall, L., Hernandez, A., Ojala, A.E.K., Abrook, A., Kosonen, E. et al. (2025) Consistent response of European summers to the latitudinal temperature gradient over the Holocene. *Nature Communications*, 16, 9969. Available from: https://doi.org/10.1038/s41467-025-65804-x

Masson-Delmotte, V., Schulz, M., Abe-Ouchi, A., Beer, J., Ganopolski, A. & González Rouco, J.F. et al. (2014) Information from paleoclimate archives. In: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K. & Boschung, J. et al. (Eds.) *Climate Change 2013—the physical Science basis. Working group I contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, pp. 383–464. Available from: https://doi.org/10.1017/CBO9781107415324.013

Meadow, A.M., Ferguson, D.B., Guido, Z., Horangic, A., Owen, G. & Wall, T. (2015) Moving toward the deliberate coproduction of climate science knowledge. *Weather, Climate, and Society*, 7, 179–191. Available from: https://doi.org/10.1175/WCAS-D-14-00050.1

O'Kane, T.J., Scaife, A.A., Kushnir, Y., Brookshaw, A., Buontempo, C. & Carlin, D. et al. (2023) Recent applications and potential of near-term (interannual to decadal) climate predictions. *Frontiers in Climate*, 5, 1121626. Available from: https://doi.org/10.3389/fclim.2023.1121626

Pearson, H. (2024) Science could solve some of the world's biggest problems. Why aren't governments using it? *Nature*, 636, 26–30. Available from: https://doi.org/10.1038/d41586-024-03906-0

Research Excellence Framework 2029. (2025) *Section 6—Engagement and Impact guidance* Available at: https://2029.ref.ac.uk/guidance/section-6-engagement-and-impact-guidance/ [Accessed 18th February 2026].

Rosemartin, A., Crimmins, T.M., Gerst, K.L., Posthumus, E.E., Ramirez, A.R., Wallace, C.S. et al. (2023) Lessons learned in knowledge co-production for climate-smart decision-making. *Environmental Science & Policy*, 141, 178–187. Available from: https://doi.org/10.1016/j.envsci.2023.01.010

Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., Baak, A. et al. (2016) The FAIR guiding principles for scientific data management and stewardship. *Scientific Data*, 3, 160018. Available from: https://doi.org/10.1038/sdata.2016.18

World Meteorological Organization. (2023) *2023 State of climate services for health*. Available at: https://wmo.int/publication-series/2023-state-of-climate-services-health [Accessed 15th January 2026].