Policy Report

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Scientists for Biodiversity

Bringing Biodiversity into Solar Radiation Modification Discussions



This report was led by Scientists for Biodiversity (S4B; https://scientists4biodiversity.co.uk), of which many of the authors are members. S4B uses its combined expertise, and works with others, to deliver focused, timely reports that clearly articulate the science behind focal issues of relevance to biodiversity management and conservation in the UK, and that provide scientifically-grounded policy recommendations.







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Executive Summary

The world stands at a critical crossroads in its response to a rapidly escalating environmental crisis. Climate change, biodiversity loss, ecosystem degradation, and increasing pressures on natural resources are creating growing urgency to act. In this context, there is a strong temptation to look for novel interventions that promise quick and scalable results. One set of interventions that is being increasingly discussed as a potential response to global heating is Solar Radiation Modification (SRM). This report is not a comprehensive technical assessment of SRM. Instead, it sets out why biodiversity and ecosystem service risks must become central to United Kingdom (UK) and international SRM research, assessment and governance. SRM cannot be assessed only through climate and technical lenses because the assessment of the potential impacts on ecosystems is fundamental to any responsible evaluation of planetary-scale intervention.

SRM refers to a suite of proposed technologies designed to reflect a proportion of incoming solar radiation back into space to reduce global temperatures. There is strong evidence – coming primarily from natural analogues, observations and climate modelling – that such approaches could help reduce the planet's average surface temperature (National Academies of Sciences, Engineering, and Medicine 2021). While no SRM technology has been deployed at scale, scientific research, technology development, and proposals for outdoor field experiments are accelerating internationally, and particularly in the UK.

Despite growing interest in SRM, biodiversity considerations have, to date, remained largely peripheral to debates that have focused primarily on cooling outcomes, technical feasibility, and governance and regulatory challenges. This report illustrates how biodiversity impacts must not be treated as secondary considerations or assumed to track climate outcomes. While climate change itself poses severe and escalating threats to biodiversity, interventions that significantly alter the Earth's radiation balance could generate a wide range of ecological consequences. Many of these remain far less studied than the cooling effects of SRM, leaving major knowledge gaps regarding risks to species, habitats, and importantly, ecosystems and ecosystem services.

Changing the amount of sunlight reaching the Earth on a large scale would inevitably affect nature: most organisms and ecosystems depend, directly and indirectly, on sunlight and natural light cycles. Impacts would come on top of existing pressures caused by people, such as climate change, pollution and land-use change. Together, these pressures could lead to further loss of wildlife, make ecosystems more vulnerable, and weaken the delivery of ecosystem services people rely on, such as food, clean water, protection from extreme weather and pollination.

The UK is becoming a significant SRM research funder. As such, UK research choices are likely to shape international norms, governance expectations and deployment pathways. As investment in SRM research continues to grow, the UK has an opportunity to champion a foresighted, interdisciplinary, and globally inclusive approach to Earth System governance that

recognises biodiversity impacts as a fundamental criterion against which SRM proposals must be judged. This would be wholly in alignment with the UK Government's approach to Responsible Research and Innovation (RRI). SRM is moreover inherently transboundary: its climatic, ecological, political and governance consequences would be distributed across regions, ecosystems and societies globally. Hence, UK research and policy need to be assessed not only against domestic legal duties, but also against the UK's responsibilities under international biodiversity, climate and environmental governance frameworks.

This report thus makes four key recommendations to the UK government:

- **UK feasibility assessments for SRM should meet national biodiversity duties and the Convention on Biological Diversity expectations;**
- **UK oversight of SRM should prevent domestic lock-in and avoid setting international precedents for weak governance;**
- **UK mitigation-first messaging should apply at home and in international climate diplomacy;**
- **The UK should advocate for international governance of SRM that gives real decision-making weight to impacts on biodiversity.**

Decisions made today could shape the trajectory of both human societies and the natural world for decades, yet they must be made under uncertainty about their costs and benefits. This makes it essential to assess proposed interventions not only for their potential gains, but also for the risks that they could create unintended consequences, including environmental harms that may be difficult, costly, or even impossible to reverse.

Constructive progress in discussions around responses to the environmental crises humanity faces, such as SRM, therefore requires a shift to whole systems thinking. Biodiversity considerations must be moved from the margins to the centre of SRM research, assessment, and governance. This will require substantial investment in biodiversity-focused research; stronger interdisciplinary collaboration between climate scientists, ecologists, social scientists and hydrologists; and governance frameworks that treat potential harms to the biosphere as a central rather than peripheral concern.

1 Introduction

Climate change is accelerating, driving record-breaking global temperatures, rapidly accelerating sea-level rise, and fuelling intense, frequent extreme weather events like heatwaves, floods, and droughts. These changes have severely impacted the United Kingdom (UK) in recent years, bringing unprecedented heat and rainfall as well as devastating wildfires. The European Forest Fire Information Service recorded 2025 as the UK's worst wildfire year on record, with approximately 47,879ha burned, and 181 fires larger than 30ha (EFFIS 2025). With the country warming faster than the global average, and recent warming far exceeding any temperatures observed in at least 300 years, these shifts have strained infrastructure, threatened human health and amplified the UK's exposure to critical food and water security challenges (Kendon et al. 2025).

The UK is legally committed to reaching net zero by 2050 and climate change acceleration has prompted welcome efforts to strengthen actions towards that goal. The current draft of the seventh carbon budget, for example, proposes a carbon budget equivalent to emissions reductions of 87% from 1990 levels by 2042 (House of Commons Library 2026). However, many have expressed doubts around the capacity to deliver on these plans, and UK climate strategies have twice been challenged in court (in 2022 and 2024) for lacking sufficient detail. In parallel, challenging economic and geopolitical conditions have contributed to increasing political polarisation around climate change, with some parties now questioning or opposing net zero policies and presenting them as costly, elitist or detrimental to economic growth. These perspectives do not always fully reflect the long-term costs of inaction or the strong evidence that early action can help reduce future costs.

Escalating climate impacts, recent extreme events (such as the 40°C barrier broken in 2022 and record flooding in 2023-24), as well as the fragility of political consensus on net zero have all helped reinvigorate interest in technological solutions to the climate change crisis. Proponents of such approaches often claim that managing overshoot of the Paris Agreement goal of 1.5˚C global average temperature increase by 2100 may not be possible through current mitigation efforts alone (see e.g., Climate Overshoot Commission 2023), while progress on adaptation has, to date, been insufficient. As such, they argue that deliberate geoengineering, particularly Solar Radiation Modification (SRM) techniques, should be seen as a supplementary tool that can help temporarily reduce temperature – and thus some climate risks – while decarbonisation and local adaptation efforts continue.



2 Solar Radiation Modification (SRM): UK research in an international governance context

Solar Radiation Modification (SRM), also known as solar geoengineering, refers to deliberate, large-scale actions intended to decrease global average surface temperatures by increasing the reflection of sunlight away from the Earth (Russell et al. 2012). The existing international governance landscape for SRM is detailed in Box 1, with the United Nations Convention on Biological Diversity (CBD) highlighting the need to regulate potential biodiversity impacts.

SRM is an umbrella term that brings together approaches that significantly differ in where and how they modify radiation. These include Stratospheric Aerosol Injection (SAI), Surface Albedo Modification (SAM), Cirrus Cloud Thinning (CCT), Space-Based Reflectors (SbR) and Tropospheric Aerosol Injection (TAI, which includes Marine Cloud Brightening (MCB); Table 1 and Figure 1). These approaches vary in terms of (i) their impacts on the spectral and angular properties of surface radiation as well as on the proportion of direct-to-diffuse surface radiation (see Box 2); (ii) the spatial scale they address and at which effects are felt; (iii) the lifespan of their impact (from days to decades) unless replicated; and (iv) their costs and levels of technological complexity. They also vary with respect to what is known about them. SAI and MCB have garnered the most interest and have been most researched (Zarnetske et al. 2021). SAI, in particular, is sometimes claimed to be cheaper, technically easier and better understood than other techniques (POST 2026).

Box 1: International governance landscape for SRM

There is currently no comprehensive international treaty specifically governing SRM. Instead, governance is fragmented across existing international institutions, legal principles, and environmental agreements. Relevant assemblies, agreements and protocols include:

The Convention on Biological Diversity (CBD). CBD Decision X/33 (Conferences of the Parties (COP) 10, 2010) established a de facto moratorium on SRM, calling on Parties to "*ensure... that no climate-related geo-engineering activities that may affect biodiversity take place*" in the absence of a science-based, global, transparent, and effective regulatory mechanism. An exception was made for small-scale scientific research conducted in controlled settings, subject to thorough prior impact assessment. This position was reaffirmed at COP11, COP13, and most recently at COP16 (2024), where the language "*urges*" Parties to ensure implementation of prior decisions on climate-related geoengineering.

The London Protocol. The 2013 amendments to the 1996 London Protocol of the Convention on the Prevention of Marine Pollution by Dumping attempted to create a regulatory framework for marine

geoengineering, in particular ocean fertilisation. The amendments have not entered into force due to insufficient ratifications; the UK has accepted the amendment and was the first to do so.

The United Nations Environment Assembly (UNEA). There have been two unsuccessful attempts to establish formal SRM governance through the UNEA. At UNEA-4 (2019), a Swiss-led resolution called for a comprehensive United Nations Environment Programme (UNEP) assessment of geoengineering technologies. This resolution was withdrawn due to disagreements on the definition of geoengineering, and in particular whether carbon dioxide removal should be considered geoengineering. At UNEA-6 (2024), another Swiss-led resolution called for a scientific expert group to assess SRM specifically. This failed to receive support and was also withdrawn.

The 1976 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD). This convention prohibits hostile use of environmental modification, with SRM falling within ENMOD's definition of environmental modification techniques.

The 1985 Vienna Convention and its 1987 Montreal Protocol. Any proposed large-scale Stratospheric Aerosol Injection (SAI) deployment (see Table 1) would trigger assessment by the Montreal Protocol's Scientific Assessment Panel as sulphur in the stratosphere is a known Ozone Depleting Substance (ODS).

The United Nations Framework Convention on Climate Change (UNFCCC). Though the Paris Agreement does not explicitly address SRM, its temperature goal could, in principle, be invoked either for or against SRM deployment. No decision or guidance on SRM has been adopted under the UNFCCC.

This fragmented governance landscape matters for UK policy because national research programmes may develop faster than international rules. In the absence of a comprehensive global framework, UK decisions on research design, outdoor experimentation, biodiversity assessment and public engagement could set important precedents internationally. This increases the need for UK governance to be both domestically robust and explicitly aligned with international biodiversity decisions and principles of precaution, transparency and equity.

Importantly, the challenges these technologies seek to address are not just technological but socio-technical and ethical, opening many unanswered questions around the level of societal readiness for them.

There is, undoubtedly, increasing interest in SRM technology development and outdoor field experiments. For example, global funding for SRM research from 2007 to 2025 totalled around $340 million, around $170 million of which came from public sources. In 2025 alone, over $60 million of funding came from commercial or philanthropic sources (POST 2026). The UK is a key player in this space, having supported continued research and assessment of SRM and stressed the importance of maintaining future policy options (UNEP 2026). Public investment in understanding the technology has increased, with the country having now become one of the largest public funders of SRM research globally. Primary funding comes from the £57 million Advanced Research + Invention Agency (ARIA) programme on solar geoengineering, which includes funding for small-scale outdoor experiments (e.g., sea ice thickening, cloud

brightening). The UK also currently funds modelling research through the five-year *Modelling environmental responses to solar radiation management* programme run by the Natural Environment Research Council, with total funding of £10.5 million (POST 2026). While the UK government has clearly vocalised its present opposition to SRM deployment, this significant increase in funding and research interest could, regardless of any significant downsides (e.g., scalability issues; environmental impacts; regulatory, governance and equality concerns), create increased momentum toward deployment regardless of risks. One could imagine, for example, that, at some point, the scale and duration of outdoor experiments will make them indistinguishable from deployments in all but intention.

Moreover, there is a risk that large publicly funded programmes may increasingly position SRM as "policy-ready", not just theoretical research. Once funding is in place and expertise grows, infrastructure starts to develop, which can create a path dependency where more investment builds, scientific communities start to organise and political awareness on the topic improves. This can, in turn, increase pressure to justify funding, demonstrate results and move toward "real-world relevance". This risk is compounded by the consequences of the intensification of climate change, the pressure to "fix" global heating quickly, and the promotion of SRM by an increasingly organised community of stakeholders as a potential rapid-response tool for crisis scenarios. A related issue is that SRM research may shift climate policy priorities, particularly in the current political climate of growing opposition against the net zero agenda. Increased investment may anchor SRM as a fallback option in politicians' minds, leading to political systems potentially becoming more tolerant of warming and future deployment becoming more likely. Geopolitical tensions developing against the background of a disintegrating rules-based world order may also increase the likelihood of deployment, being seen as a tool to secure state sovereignty (see e.g., Rainey Center & SilverLining 2026).

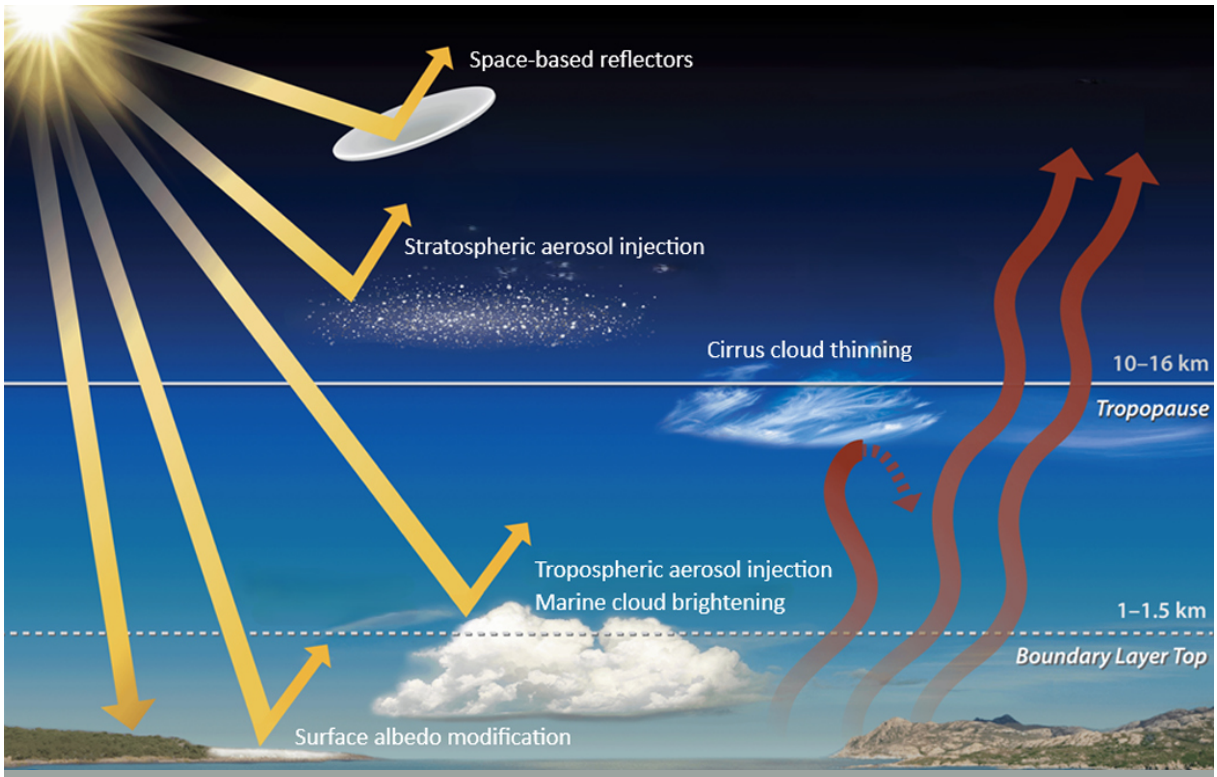


Figure 1: SRM approaches. Figure modified from NOAA (by Chelsea Thompson, NOAA/CIRES)

Table 1: Overview of SRM approaches

Type of SRM	How it works	Impacts on radiation
Stratospheric Aerosol Injection	Inject reflective particles (e.g., sulphate aerosols) into the stratosphere (≈15-25 km altitude)	Reduces total direct sunlight reaching the Earth's surface Changes the balance between direct and diffuse sunlight (more diffuse light)
Surface Albedo Modification	Make Earth's surface more reflective by, e.g., painting roofs white, using crops with higher reflectivity or deploying reflective materials in deserts	Overall, more incoming shortwave radiation is reflected back to space
Cirrus Cloud Thinning	Reduce or thin high-altitude cirrus clouds by seeding the upper troposphere with ice-nucleating particles, which forces the clouds to form fewer but larger ice crystals	Decreases optical depth and lifespan of cirrus clouds, thereby increasing escape of outgoing terrestrial heat
Space-Based Reflectors	Place mirrors or reflective particles in space to block or deflect a small fraction of incoming solar radiation before it reaches Earth	Reduces total direct sunlight reaching the Earth's surface
Tropospheric Aerosol Injection, including Marine Cloud Brightening	Introduce aerosols (e.g., sea salt particles) in lower atmosphere	Reduces total direct sunlight reaching the Earth's surface Changes the balance between direct and diffuse sunlight (more diffuse light)

3 Impacts of SRM on biodiversity and ecosystem services

Humanity relies on Earth's ecosystems to keep the planet habitable. Biodiversity – the variety of life, including genes, species and ecosystems – underpins the ecological processes that (i) regulate climate as well as air, water and soil quality; and (ii) support the provision of food, fuel, fibres, medicines and shelter. Marine and terrestrial ecosystems also absorb around half of annual human carbon emissions (Friedlingstein et al. 2025), helping to regulate Earth's surface temperature. SRM deployment has been associated with both positive and negative impacts on biodiversity (see e.g., Trisos et al. 2018; Royal Society 2025; Parry et al. 2026), though there are high uncertainties around these impacts (Huynh & McNeill 2024; Futerman et al. 2025).

Possible routes for SRM to impact biodiversity are varied (Box 2, Table 2), ranging from reduced climate-driven extinction risk, species' decline and species' relocation as the average temperature of the Earth is stabilised to changes to ecosystem processes and the emergence of novel ecological communities and ecosystems in response to novel climates and changes in water balance (Zhao & Cao 2022). The specific impacts are expected to be geographically uneven and to depend on several factors, including (i) the type of SRM considered and the way in which it is being deployed; and (ii) the timing, duration and scale at which the technology is deployed (Hueholt et al. 2024; Wells et al. 2024). For example, SAI deployment poses risks to ozone chemistry (potentially leading to increased ultraviolet (UV) radiation) and is associated with increased risks of acid deposition (i.e., acid rain when particles descend) and stratospheric heating (altering global wind and weather patterns; Huynh & McNeill 2024). The severity and certainty of these risks are influenced by the type of materials (e.g., sulphates, calcium carbonate, alumina, titanium dioxide, silica, diamond dust, zirconia) considered for SAI, with each material associated with distinct risks for ozone, stratospheric heating, and deposition. These specific risks are often poorly understood. For example, while sulphates are known to pose clear risks to the ozone layer, much uncertainty remains around these risks for calcium carbonate, alumina and titanium dioxide.

Some risks associated with potential impacts of SRM deployment are common to all SRM approaches: for example, none of the SRM approaches addresses atmospheric CO_2 concentration and the root causes of climate change, with pushes for SRM approaches potentially reducing the perceived urgency of cutting GHG emissions (McLaren 2016). Insufficient efforts to cut GHG emissions could further increase atmospheric CO_2 concentration and will be associated with continued ocean acidification (the likely range is a 0.017–0.027 pH units decline per decade, IPCC 2019), which will deprive many organisms (corals, molluscs, crustaceans, some plankton) of the calcium carbonate required for their skeleton or shell structures. This would result in catastrophic impacts on marine systems, including coral reef and marine food web collapse, with profound consequences for the provision of resources on which humanity is heavily dependent (Guinotte & Fabry 2008; Roberts et al. 2026). Rising CO_2 concentrations would not just be problematic for marine systems. CO_2 fertilisation would also influence terrestrial and freshwater ecosystems.

Box 2: Solar radiation and life on Earth

Sunlight that reaches the Earth's surface, referred to as solar radiation at sea level, is the primary source of energy for most of the life on Earth. Before reaching the Earth's surface, solar radiation (in the form of photons), passes through Earth's atmosphere, where gases and aerosol particles can interact with the energies of radiation. Photons of particular energies may be absorbed and scattered on their path to the surface. As a result, solar radiation reaching the Earth's surface differs from that at the top of the atmosphere.

Solar radiation can have different energies – and spans a broad range of wavelengths, including high energy gamma rays and ultraviolet (UV) radiation, through to visible light, and then lower-energy infrared radiation and radio waves. Different wavelengths play different roles in shaping life on Earth: plants use visible light to drive photosynthesis, UV radiation influences biological processes such as DNA repair and vitamin D production, and near-infrared radiation contributes substantially to surface heating. The balance of energy across these wavelengths, together with the proportion of direct and diffuse sunlight, shapes ecosystems, climate and the functioning of human and ecological systems.

Solar radiation reaching Earth's surface arrives as either direct or diffuse radiation. Direct radiation consists of photons travelling in a straight path from the Sun, whereas diffuse radiation has been scattered by molecules, aerosols and clouds in the atmosphere and arrives from across the hemisphere of the sky. The balance between direct and diffuse radiation is an important characteristic of the light environment, influencing how energy is distributed within plant canopies, the efficiency of photosynthesis, surface temperatures, and the behaviour and physiology of many organisms. Changes in this balance can therefore have significant consequences for ecosystem productivity, species interactions and biogeochemical cycling, even where the total amount of incoming solar radiation changes only slightly.

SRM could cause changes in the tissue stoichiometry (the balance of chemical elements) of primary producers that could be detrimental to herbivores, while rising partial pressure of CO_2 could acidify freshwater systems, affecting aquatic species and food webs (Curtis & Wang 1998; Weiss et al. 2018; Welti et al. 2020). In addition, a combination of elevated atmospheric CO_2 and reduced average temperatures might reduce plant transpiration, leading to changes to runoff and streamflow which could affect aquatic habitats, interactions between terrestrial and aquatic ecosystems, and biogeochemical processes that regulate nutrient export from watersheds (Palmer et al. 2008; Knauer et al. 2017). Interactions between temperature, precipitation, and CO_2 levels in the atmosphere may also affect the ability of ecosystems to absorb other GHGs (methane, nitrous oxide; Zarnetske et al. 2021).

Importantly, some conservation investments made under assumptions about future climate trajectories could become less effective, or require adaptation, if SRM were to produce substantially different regional climate or hydrological conditions. GHG-induced warming and SRM-induced cooling involve different physical mechanisms. Hence, SRM would not simply "undo" climate change, and the effects of climate change on regional weather patterns cannot be fully mitigated by SRM. Finally, because they do not address the root cause of climate change, SRM approaches all require continuous intervention, maintenance and eventual wind-down given that SRM is supposed to be a temporary measure only (noting that temporary, in this context, could mean multi-decade to multi-century time

spans). SRM approaches are thus associated with high operational dependence and associated ongoing costs, and lead to a situation where the Earth's average temperature would, at least for an extended period, rely entirely on the longevity and consistency of SRM projects. This creates profound systemic, ecological, and geopolitical challenges (Royal Society 2025), and would present a new security vulnerability at a time of global political instability and risks being weaponised. Chiefly, stopping deployment abruptly while atmospheric carbon remains high would cause catastrophic "termination shock" and rapid temperature spikes (McKinnon 2020). Sudden termination has been projected to increase climate velocities – the rate of climate change through time divided by the rate across space – in global biodiversity hotspots to speeds that are more than double those for recent and future climate change (Trisos et al. 2018). Such rapid change would be far more destructive to ecosystems and human populations than a slow, gradual increase. It is worth noting that termination shock could also be a product of nonhuman causes such as comet strikes, solar flares, or earthquakes.

Table 2: Non-exhaustive list of examples illustrating some of the potential consequences of SRM on biodiversity. The list primarily focusses on the more direct impacts of SRM on biodiversity, as opposed to indirect impacts that could e.g. be caused by the mining or extraction of minerals for use in SRM. In this table, **SAI** stands for Stratospheric Aerosol Injection, **SAM** for Surface Albedo Modification, **SbR** for Space-Based Reflectors, **TAI** for Tropospheric Aerosol Injection and **MCB** for Marine Cloud Brightening. The table seeks to illustrate the variety of pathways by which impacts could occur, including **(i) climate pathway:** altered temperature, precipitation, circulation and extremes affect species distributions and ecosystem stability; **(ii) hydrological pathway**: changes in rainfall, evapotranspiration, runoff and freshwater systems affect ecosystem structure, composition and functioning; **(iii) radiation pathway**: changes in total, direct/diffuse and spectral radiation affect photosynthesis, phenology and behaviour; **(iv) chemistry pathway:** ozone, aerosols, acid deposition, oxidative chemistry and pollution affect organisms and habitats; **(v) land use pathway**: physical modification of landscapes to increase albedo leads to deforestation and loss of natural habitats; **(vi) governance/path dependency pathway**: SRM research and deployment risks affect conservation planning and political priorities; and **(vii) termination pathway:** abrupt cessation creates rapid climate velocities and severe ecological disruption.

SRM type	Pathway type	Process and possible impacts	References
SAI, TAI, SbR	**Climate pathway** Reduced incoming sunlight alters temperature gradients, changes atmospheric circulation and rainfall patterns	Reduced global temperature leads to increased land carbon storage primarily because of increased CO_2 fertilisation	Parry et al. (2026)
		Shifting rainfall belts lead to water stress, ecosystem reorganisation and potential ecosystem collapse	Zarnetske et al. (2021)
		Conservation planning becomes more difficult due to climate instability and uncertainty	Trisos et al. (2018)

SRM type	Pathway type	Process and possible impacts	References
SAI, TAI, SbR	**Climate pathway** Reduced incoming sunlight alters temperature gradients, changes atmospheric circulation and rainfall patterns	Increased risks of extreme climatic events (droughts, floods) impact primary productivity, species abundance and ecological communities, leading to impaired functioning of ecosystems	Thakur et al. (2022)
SAI, TAI, SbR	**Hydrological pathway** Alteration to evapotranspiration, moisture availability and hydrological cycling, leading to changes in vegetation productivity, ecosystem functioning and species distributions	- Less incoming sunlight reduces energy needed for evaporation from soils and plant surfaces, reducing evapotranspiration even if rainfall remains unchanged - Changes in evaporation and evapotranspiration influence soil moisture, groundwater recharge and river flows, leading to changes in vegetation productivity and habitat suitability for plants and animals	Dagon & Schrag (2019)
SAI, TAI, SbR	**Radiation pathway** Widespread reduction in total solar radiation	Changes in primary production, especially when combined with shifting regional rainfall, weakens entire food chains, potentially leading to declines in biomass and species richness	Cao (2018)
SAI, TAI	**Radiation pathway** Change in the balance between direct and diffuse sunlight	Altered plant growth patterns, leading to changes in species interactions and carbon cycling. These changes then cascade through food webs, impacting ecosystem functioning	Kanniah et al. (2013)
SAI	**Chemistry pathway** Damaged stratospheric ozone layer	Subsequent increase in UV radiation damages species populations (particularly amphibians) as well as terrestrial and marine primary productivity, altering food webs	Mmbando & Ngongolo (2024)

SRM type	Pathway type	Process and possible impacts	References
TAI/MCB	**Chemistry pathway** Sea salt aerosols release reactive halogens which decrease tropospheric ozone and OH radicals while increasing methane lifetime	Changes in oxidative chemistry negatively affect plant physiology and primary productivity, leading to cascading effects on ecosystems through food webs	Ainsworth et al. (2012)
TAI/MCB	**Chemistry pathway** Tropospheric SRMs modify atmospheric chemistry in the breathable air layer, increasing air pollution and particulate matter exposure	Increased Particulate Matter (PM) exposure causes respiratory distress, DNA and tissue damage in wildlife as well as suppressed immune systems	Sanderfoot & Holloway (2017)
TAI/MCB	**Chemistry pathway** Injected particles are rapidly removed by precipitation and deposited onto land and ocean, increasing pollution	Salt deposition (in the case of MCB) leads to localized salinisation and changes in nutrient cycling, ultimately impacting terrestrial and marine primary productivity, leading to cascading effects on ecosystems through food webs	Daliakopoulos et al. (2016)
SAI	**Chemistry pathway** SAI involving injecting sulphur dioxide (SO_2) into the stratosphere leads to SO_2 being converted into sulphate particles, which are eventually deposited onto land and water surfaces	Acid rains lead to soil acidification and freshwater ecosystem damage and change	Driscoll et al. (2001)
SAM	**Land use pathway** Physical modification of landscapes to increase albedo, including deforestation, artificial surface coatings	Increased habitat fragmentation and habitat loss; habitat complexity reduction through loss of vegetation structure; physical covering blocking light penetration (impacting soil health)	Haddad et al. (2015)
SAM	**Chemistry pathway** Introduction of artificial substances into ecosystems, such as microbubbles, reflective particles, or plastics on ice	Increased levels of pollution harm organisms and create changes in relative abundance and wider ecosystem effects	Rochman et al. (2016)

SRM type	Pathway type	Process and possible impacts	References
SbR	**Radiation pathway** SbR alter the timing, intensity, and quality of incoming sunlight	Sunlight influences flowering, breeding, migration, phenology and seasonal cycles. Altered light regimes cause timing mismatches, which reduce reproductive success and potentially destabilize ecosystems	Zarnetske et al. (2021)
All	**Governance/path dependency pathway** SRM research and deployment risks affect conservation planning and political priorities	Some conservation investments become less effective, or require adaptation, as SRM is deployed	Trisos et al. (2018); Dagon & Schrag (2019)
SAI	**Termination pathway** SRM termination increases biodiversity risks by creating situations where termination shock generates climate velocities far beyond those typically experienced by wildlife	Abrupt termination of SRM could generate extremely rapid shifts in temperature and precipitation conditions, creating major challenges for species persistence and movement	Trisos et al. (2018)

4 Potential for environmental injustice

The previous section makes a clear point: SRM deployment is unlikely to affect ecosystem services evenly across the globe**.** Climate responses to SRM are expected to vary geographically (Wang et al. 2025; Parry et al. 2026) with some regions (e.g., the tropics; see e.g. Narenpitak et al. 2024; Nimusiima et al. 2025) potentially experiencing greater changes in temperature, precipitation, hydrology, and disturbance regimes than others. This could lead to biodiversity-rich regions being disproportionately put at risk from SRM deployment, including tropical and subtropical countries that support large numbers of endemic species and provide globally important ecosystem services. These same regions often already face other conservation challenges, such as habitat fragmentation, land-use change, limited conservation funding, and weak institutional capacity. SRM-induced shifts in climatic patterns, water availability or species interactions could therefore compound existing pressures, potentially reducing ecosystem resilience and undermining conservation investments that were designed around alternative climate trajectories. Because it would generate uneven regional outcomes and associated unresolved trade-offs, SRM thus has strong potential to exacerbate environmental injustice (Zhao & Cao 2022), a factor deeply intertwined with the root causes of ecological destruction.

Such concerns are amplified by asymmetries in SRM governance. Regions that may experience the greatest ecological consequences, including many countries in the Global South, currently have relatively limited influence within emerging discussions on SRM research, governance, and potential deployment. This raises fundamental questions about procedural and distributive justice: whose biodiversity is considered when evaluating the benefits and risks of SRM, and who has the authority to determine what level of biodiversity loss is acceptable in pursuit of broader climate objectives? Decisions about acceptable biodiversity risk inevitably involve value judgements that extend beyond scientific assessments of ecological change. They require balancing potentially competing priorities across different regions, while accounting for historical inequalities in responsibility for climate change and capacity to adapt to environmental change. Consequently, any assessment of SRM impacts on ecosystem services is not only shaped by ecological outcomes but also by the governance processes through which risks are evaluated, represented, and distributed among those who stand to gain or lose the most (Jinnah et al. 2026).



5 Key recommendations

As illustrated by the recent publication of the "*Global biodiversity loss, ecosystem collapse and national security*" report released by the UK government, biodiversity loss is increasingly seen as a security issue, with the potential to impact the global supply of food and emergence of diseases, and to have widespread human impact through the geo-political and market consequences that would follow. Whilst decades of effort in climate science provides the evidence and modelling basis for robust prediction of future climate under different amounts of radiative forcing, the same is not true of ecosystem science. Given this lack of predictive robustness, and yet plausible significant consequences for humanity, we here build on previous recommendations and focus on actions that we feel are of particular relevance to the UK government at this moment in time. These are summarised below.

1. UK feasibility assessments for SRM should meet national biodiversity duties and the Convention on Biological Diversity expectations

The UK has adopted and is currently implementing the CBD's Kunming-Montreal Global Biodiversity Framework, which commits the UK to intensify efforts to halt and reverse biodiversity loss nationally and internationally. In addition, all UK nations have legally binding biodiversity targets (England and Northern Ireland through the Environment Act 2021; Wales through the Environment (Principles, Governance and Biodiversity Targets) Act 2026; Scotland through the Natural Environment Act 2026). Moreover, recent CBD decisions urge a moratorium on geoengineering that may affect biodiversity (Box 1). The impacts of SRM on biodiversity must be considered within those legal framings.

As discussed above, there remains substantial uncertainty about the impacts of current SRM proposals on biodiversity (Huynh & McNeill 2024; Futerman et al. 2025). It is conceivable that SRM might reduce biodiversity loss through a reduction in global warming. While this may be true in some circumstances (Parry et al. 2026), biodiversity does not respond solely to temperature. Ecological systems are also sensitive to seasonal cues, solar radiation, cloud cover, hydrology, and changes in ecological interactions. A major concern is that SRM research funding is disproportionately focused on atmospheric science and engineering compared with ecology and biodiversity, with much of the evidence base being derived from climate models designed to assess temperature and precipitation rather than ecological resilience. SRM research emerged from these scientific communities, which naturally shaped the questions asked and research funded. Altogether, this substantially increases the likelihood that ecological risks are significantly underestimated in subsequent policy development and implementation by governments and other decision makers.

As such, the UK government should (i) nationally commit to the de facto moratorium, established under recent CBD decisions, on larger-scale interventions at least until

biodiversity risks have been properly assessed, in line with the government's own RRI frameworks; (ii) require independent ecological review for any outdoor experiment; and (iii) establish an independent expert panel, or task an existing one (such as, for example, the newly launched Climate and Nature Security Taskforce), to identify, among other things, worst-case ecological outcomes of SRM deployment. Such a panel should include conservation biologists, ecosystem scientists, evolutionary biologists, marine ecologists, social scientists and ecological economists. The panel's mandate would be to challenge assumptions about the ecological impacts of SRM made by SRM advocates rather than to promote or oppose the technology.

2. UK oversight of SRM should prevent domestic lock-in and avoid setting international precedents for weak governance

The emergence of a growing community whose careers, institutions, and funding streams are dependent on SRM is concerning, with history showing that technological communities (particularly if backed by powerful political and economic actors) can become influential policy advocates once established. A recent UK Parliament's POST review has highlighted governance concerns associated with future deployment pressures and unilateral action, for example by states, militaries or private corporations. To avoid creating a self-reinforcing technological lock-in (Foxon 2014), the UK should (i) separate research funding from deployment decisions; (ii) establish independent oversight and regulatory bodies that include ecologists and civil society representatives; and (iii) prevent research programmes from becoming de facto deployment programmes.

3. UK mitigation-first messaging should apply at home and in international climate diplomacy

As climate change continues to intensify, there is a growing risk that pushes for SRM development add to current political pressure to reduce ambition on emissions reductions. Yet SRM does not address GHG concentrations or the root causes of climate change, and is not a substitute for mitigation or adaptation. The UK is currently perceived by many as a global political leader on addressing the entwined climate and nature crises, with, for example, (i) the UK government explicitly framing climate change and biodiversity loss as interconnected challenges that require integrated solutions in its 2025 "*Actions to jointly address climate change and biodiversity loss in England*" report; (ii) the Joint Nature Conservation Committee (JNCC) and the Climate Change Committee formalising closer collaboration that year, reflecting growing institutional integration of climate and biodiversity science; and (iii) the launch of the previously mentioned taskforce to provide independent recommendations and expertise on climate and nature threats to national security. As such, the government should continue clearly and regularly to communicate that emissions reductions and ecosystem recovery are, and will remain, the primary strategy to address climate change mitigation, adaptation and biodiversity loss. These communications should be matched with investments in these strategies, at home and abroad.

4. *The UK should advocate for international governance of SRM that gives real decision-making weight to impacts on biodiversity*

At present, there is no governance framework addressing Earth System risks, such as those posed by SRM. Current SRM governance discussions are dominated by climate science, atmospheric science, and engineering perspectives. Although SRM poses profound and often irreversible risks to biodiversity, the biodiversity community remains insufficiently engaged in SRM discussions and decision-making processes. There is no doubt that biodiversity, given its fundamental role in supporting human wellbeing, should be central to decision-making regarding interventions that may have large or planetary-scale consequences. As such, we urge the UK government to advocate for (i) a new international treaty that addresses Earth System risks posed by SRM with governance structures that explicitly include voices from ecosystem scientists; conservation organisations; Indigenous and local knowledge holders; as well as ecological monitoring networks; and (ii) governance architectures in which biodiversity outcomes carry genuine decision-making weight.

6 Conclusions

SRM is increasingly being discussed as a potential response to the growing risks associated with global heating. To date, however, debates surrounding SRM have been dominated by questions of climatic effectiveness and technical feasibility, while the implications for biodiversity have received comparatively limited attention. Huge uncertainties remain about the likely effectiveness of SRM in limiting temperature increases and avoiding the risk of crossing key climatic tipping points (Futerman et al. 2025). Crucially, huge uncertainties also remain when it comes to the risks these technologies pose to our ecosystems and the services that they provide and that we depend on. Biodiversity underpins human wellbeing, regulates climate, supports food and water security, and is already experiencing unprecedented pressures from habitat loss, climate change, pollution, and overexploitation (IPBES 2019). In discussions about SRM, much greater weight should be placed on irreversibility, ecological uncertainty, and the possibility that a globally deployed technology could create biodiversity losses that are difficult or impossible to reverse even if average global temperatures decline.

To ensure that SRM discussions are grounded in the full range of environmental risks and follow RRI frameworks, it is essential that biodiversity considerations are moved from the margins to the centre of SRM research, assessment and governance. There must be a substantial increase in biodiversity-focused research alongside the development of responsible governance and regulatory principles that place potential ecological harms and wider Earth System feedbacks at their core. Ecological risks and opportunities should be evaluated alongside climatic, technical, economic, social and geopolitical considerations, and ecological expertise should be systematically included in national and international decision-making processes. Future UK SRM research programmes should devote substantially greater attention and resources to understanding ecological consequences across terrestrial, freshwater, and marine systems, particularly in regions of high biological importance and vulnerability.

In conclusion, UK SRM governance must be internationally coherent because national research choices could have ecological, political and governance consequences well beyond UK borders. Given SRM's transboundary effects, the current gap between fast-moving research and slower international rulemaking, and the UK's commitments under the CBD, any UK approach should be foresighted, biodiversity-centred and globally inclusive. The UK is well positioned to provide leadership in this area: as investment in SRM research grows, it has an opportunity to champion a foresighted, interdisciplinary, and responsible approach that ensures biodiversity-rich and climate-vulnerable countries have a meaningful voice, and that biodiversity is treated as a fundamental criterion against which SRM proposals are judged. Doing so would reflect a commitment to a rigorous, more holistic, assessment of interventions at planetary scale, while helping to ensure that UK-funded research does not inadvertently set weak precedents for future deployment or imply that deployment is an inevitable destination.

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