SCIENCE & EVIDENCE

Threats and pressures on adders (*Vipera berus*) and sand lizards (*Lacerta agilis)* in the UK: a quick scoping review






Executive Summary

Background and Policy Context

Adders (*Vipera berus*) and sand lizards (*Lacerta agilis*) are two of the UK's most threatened native reptiles, with both species experiencing significant declines in distribution and abundance over the past century. These declines are largely attributed to habitat loss, fragmentation, and degradation, compounded by ecological specialisation of these species and isolated populations vulnerable to local extinction and genetic bottlenecks.

Despite legal protections under UK legislation, enforcement and habitat management remain inconsistent, and threats such as climate change, public disturbance, inappropriate land management, and potentially emerging pressures including gamebird release, continue to pose risks. Gamebird release, particularly of pheasants, has raised concerns due to potential impacts on threatened reptile habitats, increased predation, and disturbance, though the evidence base remains limited.

The UK's legally binding biodiversity targets under the Environment Act 2021, such as halting species decline by 2030 and increasing species abundance by 10% by 2042, highlight the urgency of addressing these pressures through evidence-based conservation strategies that consider both established and emerging threats.

QSR process and methodology

This Quick Scoping Review (QSR) assessed evidence on the threats and pressures on adders *(Vipera berus*) and sand lizards (*Lacerta agilis*) in the UK. The review included peer-reviewed and high-quality grey literature but did not critically appraise individual studies. As such, the review provides an overview of the available evidence rather than a ranked evaluation of its quality or robustness.

Evidence base characteristics

The QSR reviewed 44 studies, comprising 23 peer-reviewed journal articles and 21 pieces of grey literature, including theses, organisational reports, and conference papers. Most studies were published between 2010 and 2025, and the majority of studies were from England (n=31). The studies covered a range of habitats, with lowland heathland (59%) and woodland/forest (52%) most frequently represented, followed by grassland and scrubland (39%), coastal sand dunes (36%), and urban/brownfield sites (30%). These reflect the habitat preference of the focal species rather than national habitat extent. Adders were the primary focus in 23 studies, sand lizards in 13, and both species in eight studies.

Key findings

Many studies discuss multiple, overlapping threats and pressures, therefore the percentages reported below reflect the frequency rather than proportionality. Habitat loss and fragmentation was the most frequently cited threat (86%), followed by anthropogenic disturbance and persecution (55%), inappropriate management (48%), climate change (39%), and infrastructure and development (34%).

Threat severity ranged from local extirpation to reduced breeding success and increased mortality, with over a third of studies reporting severe population impacts. Adders were more frequently affected by genetic bottlenecks, translocation-related risks, and historic persecution, while sand lizards faced greater challenges related to breeding habitat degradation and climate sensitivity.

Mitigation measures were widely discussed, with habitat management being the most commonly studied and often effective. Translocation showed mixed outcomes and was frequently ineffective without robust planning and monitoring.

Notably, none of the studies assessed these impacts at a national scale. Only four studies referenced the UK or Great Britian, and of these, just one was a peer-reviewed journal article. The others addressed broader themes or conservation guidance rather than directly evaluating threats and pressures on adders or sand lizards.

QSR limitations

As a QSR, this review does not include critical appraisal of study quality, nonetheless, consistent patterns across multiple studies and contexts can still inform policy and practice as well as highlight knowledge gaps.

Implications for policy, practice, and research

The findings underscore the need for targeted, evidence-based conservation strategies that prioritise habitat management and connectivity, and species-specific requirements. Translocation should be considered cautiously and requires robust assessment of release habitat and monitoring to assess outcomes. Public engagement and education could be utilised and plays a role in reducing any ongoing persecution and anthropogenic disturbance.

Policy implementation should be consistent across regions, with better integration of reptile conservation into broader land-use planning and biodiversity frameworks. Long-term monitoring and standardised data collection are essential to evaluate mitigation success and inform adaptive management.

One emerging concern is the potential impact of gamebird release, particularly pheasants, on threatened reptile populations like adders and sand lizards. Although only three studies directly referenced pheasants as a threat, two of which highlight predation and the other rearing practices, they provided limited details and highlighted some of the evidence is anecdotal (Gardner et al., 2019; Julian & Hodges, 2019; Gleed-Owen & Langham, 2012). As part of a programme of DEFRA funded research into the impacts of gamebirds, a PhD research project is currently underway with the aim of comparing the distribution of gamebirds and reptiles in southeast England.

While the evidence on many pressures is limited, all must be considered within the broader threat landscape, and mitigation measures implemented, for example in areas where gamebird release may compound known threats such as habitat degradation, disturbance, or predation risks.

Future research should address key evidence gaps, including cumulative impacts, genetic vulnerability, and the effectiveness of mitigation strategies. Priorities include long-term monitoring, standardised survey protocols, genomic studies, and better integration of reptile conservation into wider land-use and policy frameworks. Upcoming studies on gamebird release should be interpreted within the broader context of multiple pressures to ensure balanced, evidence-led conservation responses.

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1. Background

Adders (*Vipera berus*) and sand lizards (*Lacerta agilis*) are two of the UK's most threatened native reptile species. Both have undergone significant declines in distribution and abundance over the past century, largely due to habitat loss, fragmentation, and degradation (Gardner et al., 2019). These declines are particularly concerning given the species' limited and often isolated populations, which are vulnerable to local extinction and genetic bottlenecks.

In the UK, adder populations have declined in both range and abundance, with some studies estimating local extinctions in up to 90% of historical sites in parts of England (Gardner et al., 2019). Sand lizards were once widespread across southern heathlands and coastal dunes, but now are restricted to a few fragmented strongholds, with reintroduction efforts attempting to restore populations in former habitats (Moulton & Buckley, 2015). These declines are compounded by the species' ecological specialisation, with sand lizards requiring open sandy areas suitable for egg-laying, and adders depending on structurally diverse habitats for thermoregulation and hibernation.

The primary threats to both species include habitat loss and fragmentation due to urban development, agricultural intensification, afforestation, and infrastructure expansion (Law et al., 2020). Habitat degradation, including scrub encroachment, inappropriate grazing, and lack of active management, further reduced habitat suitability (Law et al., 2020). Climate change is also emerging as a significant pressure, with altered temperature and precipitation patterns affecting reptile phenology, breeding success, and habitat connectivity (Hodges, 2022). For example, reduced sunshine during key breeding months has been linked to lower reproductive success in sand lizards in northwest England (Jackson, 1978).

In addition to environmental pressures, human disturbance, persecution and predation by domestic animals (e.g. cats) pose direct threats, particularly to adders. Public misunderstanding and fear of snakes can contribute to persecution, while increased recreational access to sensitive habitats can disturb basking or breeding individuals (Gardner et al., 2019).

From a policy perspective, both species are protected under UK legislation. They are listed under Schedule 5 of the Wildlife and Countryside Act 1981 and are priority species under the 2024 UK Biodiversity Framework (Joint Nature Conservation Committee, 2024). Sand lizards are also protected under the EU Habitats Directive/The Habitats Regulations, requiring the designation and management of Special Areas of Conservation (The Conservation of Habitats and Species Regulations 2017, 2017; Joint Nature Conservation Committee, n.d.). Despite these protections, enforcement and habitat management remain inconsistent across regions.

The UK government's legally binding targets under the Environment Act 2021, which sets out to halt species decline by 2030 and increase species abundance by 10% by 2042, underscores the urgency of addressing these threats. Effective conservation of adders and sand lizards will require targeted habitat restoration, improved landscape connectivity, and evidence-based management practices. This includes the use of translocation (where suitable and followed by monitoring), informed regimes of controlled burning and grazing to maintain mosaic habitat structures, and public engagement to reduce persecution and disturbance (Law et al., 2020).

However, the evidence base for many of these threats and interventions remains patchy. While some studies report positive outcomes from habitat management and reintroduction, others highlight key knowledge gaps around long-term population viability, genetic health, and the cumulative impacts of multiple pressures (Gardner et al., 2019). One emerging concern is the potential impact of gamebird release on reptile populations, particularly those that are vulnerable or threatened like adders and sand lizards, through habitat disturbance, increased predation, and disease transmission. Although this issue has prompted growing interest, with a new study due to be published, it remains under-researched and poorly understood (Gardner et al., 2019).

A robust synthesis of the current evidence is therefore essential to inform future conservation strategies and policy decisions. This Quick Scoping Review (QSR) aims to collate the available literature on threats and pressures facing adders and sand lizards in the UK, with a focus on identifying key drivers of decline, including gamebird release, evaluating the effectiveness of mitigation actions, and highlighting knowledge gaps where further research is required.

1.1 Project Aims and Objectives

This project undertakes a Quick Scoping Review (QSR) to collate peer-reviewed and high-quality grey literature on the threats and pressures facing adders (*Vipera berus*) and sand lizards (*Lacerta agilis*) in the UK. The review aims to:

- Identify and categorise the types and sources of threats and pressures studied.
- Assess the severity and implications of these threats for UK populations.
- Identify and evaluate the effectiveness of mitigation strategies.
- Highlight evidence gaps and inform future research and policy, including in relation to gamebird release.

1.1.1 Research Outputs

The outputs of this report are:

1. A synthesis of the quantity, characteristics, and findings of the evidence base on threats, pressures, any mitigation strategies for adders and sand lizards in the UK, with relevance to current and future policy decisions, including those concerning gamebird release.
2. Identification of key evidence gaps and implications for future research and conservation practice.

2. Methodology

This QSR follows DEFRA guidelines for Quick Scoping Reviews and Rapid Evidence Assessments (Collins et al., 2015). It provides a snapshot of the available literature on threats and pressures facing adders (*Vipera berus*) and sand lizards (*Lacerta agilis*) in the UK, focusing on volume, characteristics, and thematic findings of the evidence base.

A QSR is a streamlined form of systematic review that enables rapid synthesis of evidence, typically using fewer sources or a narrower scope and a shorter timeframe than a full systematic review. This review used Google Scholar and Web of Science to identify relevant peer-reviewed and grey literature, applying Boolean search strings (see section 2.3, table 2). Due to time and access constraints, the search may not be exhaustive; however given the limited volume of research on this topic, it is likely that the majority of high-quality and relevant literature was captured.

The review does not include a critical appraisal of study quality, and limitations are discussed in section 2.3.4. Evidence was analysed thematically in Microsoft Excel to address the following research questions.

2.1Conceptual Model



Figure 1. Conceptual model illustrating the relationships between external drivers, pressures, species vulnerabilities, conservation responses, and knowledge gaps affecting adder (*Vipera berus*) and sand lizard (*Lacerta agilis*) populations in the UK.

The conceptual model below (figure 1) outlines how broad-scale drivers such as land-use change, climate change, and recreation generate pressures including habitat loss, disturbance, and predation. These pressures interact with species-specific vulnerabilities, such as ecological specialisation and genetic isolation, to produce population-level impacts. Conservation responses, including habitat management and translocation, aim to mitigate these effects, though their success varies. Knowledge gaps and research needs feedback into policy and practice, highlighting the importance of long-term monitoring, standardised survey protocols, and integrated land-use planning to support evidence-led conservation.

2.2 QSR Scope

The Population, Intervention, Control, Outcome (PICO) elements of the primary question are shown in Table 1 below. This review focused on the results or context of the threats and pressures facing adders and sand lizards in the UK.

Table 1. Table demonstrating the PICO elements of the primary research question 'What are the threats and pressures facing adders (Vipera berus) and sand lizards (Lacerta agilis) in the UK?' (based on the methods of Collins et al., 2015).

PICO Element	QSR Element
Population	Adder (*Vipera berus*) and sand lizard (*Lacerta agilis*)
Intervention	Natural and anthropogenic threats and pressures
Control	Conservation measures / mitigation strategies
Outcome	Effects of the threats/pressures on adder and sand lizard populations in the UK

The PICO method is used to help define the questions addressed in the review and the possible outcomes of a particular policy approach. Policy and practical approaches related to different threats and pressures and mitigation strategies highlighted in the research are considered in this QSR.

The scope of the QSR was defined by the project objectives and is as follows:

- Geographical reference: Great Britain
- Climatic conditions: Temperate, maritime conditions
- Language: English only
- Population restrictions: Adder (*Vipera berus*) and sand lizard (*Lacerta agilis*) only.
- Date restrictions: None
- Search Libraries: Google Scholar and Web of Science

There were two parts to the QSR search. The first was a Google Scholar search and the second a Web of Science search of published scientific journal articles. Google Scholar was selected as one library because it is more likely to display grey literature as well as published peer-reviewed literature. Web of Science was selected because of its accessibility both in terms of journals and search string tools. Both libraries allow Boolean search strings which was the search strategy used for this QSR (see section 2.3 below)

2.2.1 QSR Research Questions

To address the objectives of the review, the following primary and secondary questions were formulated.

Primary research questions

- What are the threats and pressures facing adders and sand lizards in the UK?

Secondary research questions

- What types and sources of threats have been studied?
- What is the severity and impact of the identified threats?

- What mitigation strategies have been used, and how effective are they?
- What are the implications for policy and practice, including in relation to gamebird release?
- What evidence gaps remain, and how can future research address them?

2.3 QSR Search Method

A QSR selects evidence for screening by searching literature for key terms using a search string. The search engines used in this QSR were Google Scholar and Web of Science; the search methodology of each is detailed below, followed by the review methodology and methodological considerations. Inclusion criteria were created for the screening and data extraction process, and these were used along with generative artificial intelligence (AI) to assess whether the criteria were met for each study. These criteria can be found in the Appendix: Screening and data extraction criteria.

2.3.1 Google Scholar search methodology

Google Scholar advanced search strings are limited to 32 terms. Combinations of search terms were used to test the search string for sensitivity and validity. This highlighted that complex search strings including both species and generic terms related to threats/pressures produced very broad results, in excess of 50,000. Therefore, it was decided, following further trial-and-error sensitivity testing, that several simpler search strings would produce results of higher relevancy than all search terms in one string (Table 2).

The top 40 hits from each search - where that many were presented - totalling 95, were compiled into an Excel spreadsheet. The results were screened first by title and abstract, ensuring they were relevant to the research question and any duplicates were removed. Those that were included along with any that were marked 'unsure' (due to limited information in the title) progressed to the second screening phase which was of the full text. After screening was complete, 39 sources from Google Scholar remained to be reviewed (Figure 2).

2.3.2 Web of Science search methodology

Some initial sensitivity testing of search string was first carried out. The number of results produced from these tests ranged from 10 to 3,700. The string for the actual search was decided and produced 25 results. These results were then refined by exclusion criteria related to (1) country and (2) research areas. The outputs were exported as a .ris file and imported to Mendeley before being uploaded into an Excel spreadsheet containing the author, date, title, journal, and abstract. The 25 studies were then screened by title and abstract (8 duplicates were also removed at this stage), resulting in 7 results. Following a final full text screening, there were 6 results left to be reviewed (Figure 2).

Table 2. Population keywords, exposure qualifiers and additional qualifiers for the Google Scholar and Web of Science literature searches and screening process.

Population keyword	Exposure qualifier	Additional qualifier
adder*	"habitat loss"	distribution
"Vipera berus"	"habitat fragmentation"	chang*
"sand lizard"	"climate change"	local*

"Lacerta agilis" hibernacul*	Predation Disturbance Construction Development build* "population decline" threat* vulnerable pressure	

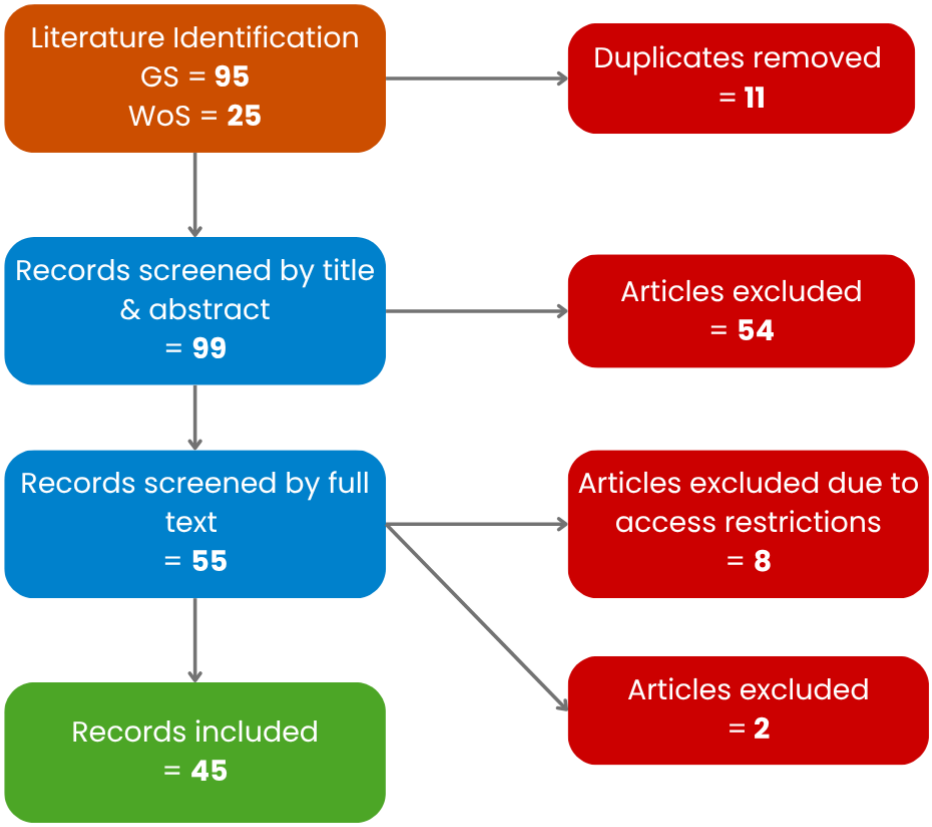


Figure 2. Flow diagram of the screening methodology and number of papers included and excluded at each stage. 'GS' refers to google scholar and 'WoS' refers to web of science.

2.3.3 Review methodology

An Excel spreadsheet containing 39 results from Google Scholar and 6 results from Web of Science was populated with columns for data collection (all references can be found in Appendix: Database reference list). These were designed to capture key pieces of information from each document. Due to time-resource constraints, Microsoft's Generative AI software, Microsoft Copilot, was used to extract initial relevant pieces of information from each document. Clear and specific instructions based on the protocol of this QSR were set out in a document and used for each study to ensure consistency. Information was extracted and organised in an excel sheet. A breakdown of this can be found in Appendix, Table 1.

2.3.4 Methodology considerations

Several methodological factors may influence the outcomes of this review. The use of Google Scholar as a search engine can introduce uncertainty regarding its algorithms, as the ranking and retrieval of studies are not fully transparent. However, this method importantly allows for the inclusion of grey literature, which might otherwise be inaccessible through academic databases, such as Web of Science and Scopus, which require institutional access. Additionally, time constraints inherent in a QSR limit the level of detail that can be extracted from each study, although the low volume of studies made this more manageable. Studies were included based on predefined criteria, but there was no initial categorisation of priority or relevance before the full evidence extraction process.

A single reviewer conducted the screening and data extraction, which may have introduced unconscious bias in the selection of search terms and manual screening process. While keyword-based screening allowed for objective exclusion of irrelevant studies, the potential for human error in the screening and evidence extraction process remains. However, the application of objective criteria (e.g. country, species, intervention), and protocol approval by the project sponsor and supervisor helped mitigate this risk. Additionally, the use of AI-assisted tools in the screening and evidence extraction process introduces an additional layer of uncertainty, as the efficacy and potential biases of such tools are not always easily identifiable. The use of clear, consistent, and strategic instructions with prior testing helped mitigate against this.

Furthermore, many studies included in this review spanned multiple categories within each topic, meaning they were counted under all relevant classifications rather than being assigned to a single category. For example, studies frequently covered multiple home nations, habitat types, threat/pressure types, or mitigation strategies, leading to overlap in reported results. Additionally, some studies discussed threats and pressures, or mitigation strategies rather than directly implementing or measuring them (e.g. theoretical modelling or conservation planning). In such cases, studies were categorised based on their perceived or predicted relevance rather than experimental results. These overlaps should be considered when interpreting the results, as they reflect the complex and multifaceted nature of the evidence base rather than distinct, mutually exclusive study types.

Future reviews could enhance reliability and robustness by incorporating multiple reviewers, ensuring transparent ranking algorithms, and implementing additional quality-control measures to improve the consistency of evidence extraction and interpretation.

3. Results

The results of this Quick Scoping Review present a synthesis of the available literature on threats and pressures facing adders and sand lizards in the UK. Many studies identified multiple overlapping threats or pressures, so the frequencies reported in the subsequent sections reflect how often each threat was mentioned rather than their proportion or contribution to decline.

3.1 Introduction to evidence base

Publication types and periods

The QSR reviewed 44 pieces of evidence (Figure 2), comprising 23 peer-reviewed journal articles and 21 pieces of grey literature, including book chapters, postgraduate theses, conference papers, and reports from conservation organisations, policy makers, and government bodies. This near 50:50 split highlights a notable lack of academic focus on the topic, with much of the available evidence emerging from practitioner-led or policy-driven sources. While grey literature can offer valuable insights, especially from field-based conservation work, its strong representation also reflects the limited volume of formal research dedicated to the threats facing these species.

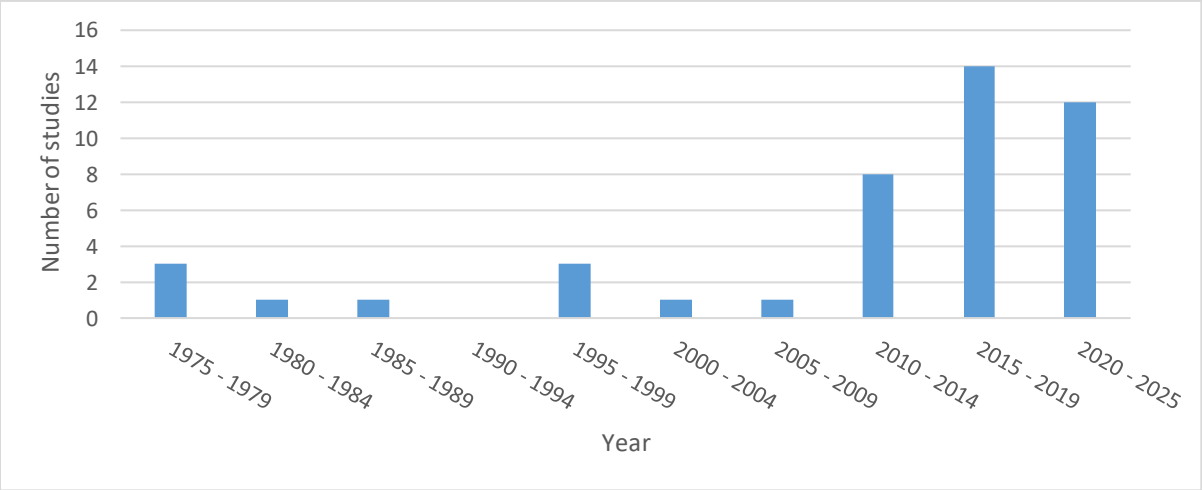


Figure 3. Number of studies in the evidence base published between 1975 to 2025, shown in 5-year intervals. The graph highlights peak periods of research activity and illustrates temporal trends in the development of the evidence base.

The majority of studies were published between 2010 and 2025, with a peak between 2015 and 2019 (n=14), and no evidence found prior to 1978 (Figure 3). This trend suggests growing interest in reptile conservation in recent decades, potentially driven by increased awareness of biodiversity loss, national policy developments, government biodiversity targets, and targeted conservation initiatives. However, the relatively small number of studies per year also indicates that research on adders and sand lizard remains sporadic, likely reflecting the niche and specialist nature of herpetology in the UK, as well as the comparatively low diversity of native reptile species, which may attract less academic attention than in countries with richer herpetofauna.

Geographic coverage

The geographical distribution of the studies in Great Britain (mainland England, Scotland and Wales) is dominated by evidence from England (n=31, 4 of which also included areas in Wales), with fewer studies in Scotland (n=7) and Wales (n=2). Studies conducted in Great Britain or the United Kingdom as collective study regions contributed 4 studies in total.

The distribution of studies is broadly representative of the three home nations of Great Britain and is therefore likely representative of the species' known distributions and habitat availability, allowing for broader geographic conclusions about the themes of the findings in this review. However, it should be noted that the strong bias toward England may also reflect where conservation activity, research funding and monitoring efforts have been concentrated. This geographic skew could influence the generalisability of findings, particularly for regions with distinct ecological conditions or management practices. It also highlights the need for more targeted research in underrepresented areas to ensure conservation strategies are informed by regionally relevant evidence and context.

Ecosystem and habitat types

Studies were undertaken in a broad range of ecosystems where adders and sand lizards would be expected to occur. Lowland heathland and woodland forests (including plantations) appeared most frequently in the database, occurring in 59% and 52% of studies, respectively. Other frequently studied ecosystems were grassland and scrubland (39%), coastal areas and sand dunes (36%), and urban and brownfield sites (30%). Wetlands and bogs (20%), transitional habitats, including path edges and rides (20%), and moorland and upland habitats (16%), were less commonly studied. This composition does not reflect the proportions of habitat extent reported in Habitat extent and condition, natural capital, UK: 2022 (Office for National Statistics, 2022) but likely reflects the habitat preferences and distribution of the adder (*V. berus*) and sand lizard (*L. agilis*) in the UK.

Several studies highlighted specific habitat features critical for breeding and hibernation. For sand lizards, open sandy areas with sparse vegetation are essential for egg-laying (House & Spellerberg, 1983), while adders rely on structurally diverse habitats, such as south-facing slopes, scrub edges, and undisturbed grassland mosaics, for thermoregulation and hibernacula (Stroud, 2011). The ecological importance of these habitats is reflected in the database, with lowland heathland and coastal sand dunes being the most frequently studied habitats for sand lizards, and a broader range of habitats studied for adders. This pattern suggests that habitats of high ecological importance for these species may attract greater research interest, although some critical microhabitats (e.g. hibernation sites) may still be underreported in the literature.

Species focus

Adders are a primary focus in 23 studies, with 10 of these including one or more other reptile species. There are 13 studies focusing on sand lizards, just over half of which included other reptiles or amphibians (n=7). A total of 8 papers studied both adders and sand lizards alongside other reptile and amphibian species. Whilst the other species included in the studies were not included in the scope of this QSR, they comprise both native and invasive species, some drawing on the impacts of interspecific competition and broad threats, habitat requirements and conservation needs.

The greater number of studies focused on adders may reflect their greater distribution across the UK (Gardner et al., 2019), greater public attention or encounters, or heightened conservation concern due to perceived declines. In contrast, sand lizards have a more restricted range and specialised habitat requirements, which may limit research opportunities and detectability (Dent, 1986). The inclusion of other reptile or amphibian species in many studies suggests that some threats and pressures may be relevant across broader herpetofauna communities or are being examined within wider ecological contexts. However, this broader scope can sometimes dilute species-specific insights, particularly when the unique ecological requirements or conservation needs of adders and sand lizards are not the primary focus. This highlights the need for targeted research that addresses the unique ecological and conservation needs of each species, particularly in relation to habitat use, population dynamics, and responses to management interventions.

3.2 Threat landscape and population impacts

Threats and pressures were empirically studied in 34 of 44 reviewed studies, using methods such as field-based observation, population monitoring, and data-driven modelling. The remaining ten studies discussed threats conceptually or anecdotally, without direct empirical analysis. The proportions of threat categories cited is based on all studies below and are then broken down by species to account for the uneven distribution of adder and sand lizard research. Threats were also ranked in their severity from 'unlikely to impact a local population' to 'likely to lead to widespread extinction'.

Across the evidence base, the most frequently cited overarching threats were: habitat loss and fragmentation (86%), public pressure and persecution (55%), inappropriate management* (48%), climate change and extreme weather (39%), and infrastructure and development (34%). These threats were consistently reported across studies focusing on both species (n=8), suggesting shared vulnerability to landscape-scale pressures and human disturbance.

*Inappropriate management typically referred to poorly timed or insensitive land-use practices, such as mowing, burning or grazing, that inadvertently harm non-target species. These findings suggest that even well-intentioned conservation or land management actions, for example to benefit other species, can pose risks to other vulnerable species if not tailored to species-specific needs within the environment.

Adder (Vipera berus)

Among the 23 adder-focused studies, habitat loss and fragmentation was the most frequently cited threat (87%), followed by anthropogenic disturbance and persecution (61%). Notably, 11 of 14 studies mentioning anthropogenic disturbance included explicit references to persecution, often linked to public fear or misunderstanding of snake behaviour and risk (Gardner et al., 2019; Hodges, 2022; Public fear & Hodges, 2019). Inappropriate management (48%) and predation/disturbance (39%) were also prominent. The latter included specific mentions of pheasants (*Phasianus colchicus*), wild boar (*Sus scrofa*) and corvids (*Corvidae spp.*), with one study also linking controlled burning (associated with grouse moor management) to increased predation risk due to changes in vegetative structure and cover (Worthington-Hill & Gill, 2019).

The ecological interface between gamebird management and reptile conservation is an emergent field of research but remains poorly understood in the context of shooting and associated management activities in the UK. Research has shown that pheasants with stronger natural foraging abilities tend to have higher post-release survival rates, which is important to gamekeepers both ethically and economically (Madden, Hall & Whiteside, 2018). Strategies to improve foraging behaviour during the rearing phase, such as providing varied perch heights and diets (including live mealworms), have been found to support this (Madden, Hall & Whiteside, 2018). However, as these strategies lead to increased natural foraging they may increase predation on available food sources, which as opportunistic feeders can include small reptiles such as young adders (Gardner et al., 2019; Dimond et al., 2013). Studies to better understand the interactions between pheasants and adders, including data on different release and enrichment strategies for gamebirds, may be worth considering.

Wild boar, now established in areas such as the Forest of Dean and the Weald, were also identified as a potential threat to adders due to their disruptive foraging behaviour, particularly around hibernacula (Julian & Hodges, 2019). Although their presence is limited, their impact on sensitive reptile habitats warrants further attention to ensure local populations are appropriately protected. Corvids, especially crows, were also noted as predators of juvenile adders. Crows are legally controllable under general licences in England, Scotland and Wales for conservation purposes, and gamekeepers already play a key role in crow control to protect both reared quarry and wild species such as nesting waders. Gamekeeper and shoot manager involvement in habitat creation and protection also positions them as important stakeholders in reptile conservation.

Less frequently cited threats included: Climate change and extreme weather (30%), infrastructure and development (30%), genetic issues (26%), translocation related risks (22%), habitat degradation (22%), and invasive species and disturbance (9%).

Threat severity was predominantly high (n=17), with fewer studies reporting moderate (n=7) or mixed/uncertain (n=3) outcomes. These severities translated into impacts such as population declines or local extirpation (n=8), often associated with genetic bottlenecks (Ball et al., 2020; Pozzi, 2023); reduced abundance and breeding success (n=8), often linked to habitat degradation, fragmentation, or suboptimal management; and increased mortality or dispersal (n=6), usually following translocation attempts. Where individuals failed to establish, dispersal was higher, which can elevate energy expenditure and predation risk during movement (Nash & Griffiths, 2018). In four studies, impacts were either not quantified or remained uncertain, which may reflect a lack of demographic data, a focus on threats without direct population metrics, or an emphasis on evaluating mitigation methods rather than impact.

Sand lizard (Lacerta agilis)

Of the 13 sand lizards studies, habitat loss and fragmentation was again the most cited threat (77%), reinforcing its likely central role in the species decline. Other frequently mentioned pressures included habitat degradation (38%), climate change and extreme weather (38%), and infrastructure and development (38%). Less commonly cited threats included public pressure

and persecution (31%), inappropriate management* (31%), predation and disturbance (15%), and invasive species and disease (15%).

Genetic issues and translocation risks were not cited in any sand lizard studies, likely reflecting species-specific differences in dispersal behaviour and genetic vulnerability. This absence may also be influenced by the widespread success of sand lizard reintroduction initiatives, which have led to re-establishment of populations in former habitats (Moulton & Buckley, 2015). As a result, follow-up research may have been considered less urgent compared to adder translocations, which have produced more variable outcomes and continue to raise concerns about dispersal-related mortality and site suitability.

Threat severity was mostly high (n=9), with moderate (n=4) and mixed/uncertain (n=3) impacts cited less frequently. Impacts were most commonly reported as reduced abundance and breeding success (n=10), often linked to habitat degradation, fragmentation, or suboptimal management. There were fewer reports of population impacts/severe declines (n=3). In three studies, impacts were not quantified or remained uncertain, again reflecting limitation in demographic data or a focus on mitigation rather than direct population metrics. The emphasis on reproductive success in sand lizard studies may reflect their specialised breeding habitat requirements and sensitivity to microclimate changes, particularly in dune and heathland systems (Jackson, 1979; Dent & Spellerberg, 1988; Edgar & Bird, 2006).

In the eight studies that examined both species, habitat loss was universally cited (100%) followed by inappropriate management (75%), public pressure and persecution (63%), and climate change and extreme weather (63%). These studies tended to adopt broader ecological or landscape-level perspectives, reinforcing shared vulnerability of both species to large-scale environmental change. However, species-specific nuances, such as differences in habitat use, dispersal, and public perception, may be underexplored in muti-species studies.

Temporal relevance

Of the studies reviewed, 15 were classed as 'historical', either analysing older datasets or published more than 15 years ago. A larger proportion, 34 studies, were deemed 'currently relevant', having been conducted within the last 10-15 years. Additionally, seven studies incorporated projections or modelling of future scenarios. This temporal distribution suggests growing focus on reptile conservation in recent years, as is supported by Figure 3, likely influenced by evolving policy frameworks, heightened awareness of biodiversity decline, and the implementation of targeted conservation efforts.

3.3 Effectiveness of mitigation

Mitigation measures were discussed or studied in 43 of the 44 studies included in this review. These were categorised thematically and summarised below based on how frequently their effectiveness was assessed and the level of effectiveness achieved. Many studies explored multiple mitigation methods in combination, so the outcomes reported here reflect general patterns rather than isolated interventions. A total of 14 studies did not directly evaluate effectiveness or the success was unknown. An additional five studies assessed effectiveness

based on expert opinion or modelling only, rather than empirical data, therefore this must be taken into consideration when interpreting the below results.

Most commonly discussed actions

The most widely studied mitigation measure was habitat management, cited in 75% of studies. This typically involved maintaining habitat connectivity, managing hibernacula and surrounding areas to reduce destruction or disturbance, and controlling vegetative cover. Techniques such as phased or strip-based cutting were recommended to promote structural diversity, which is particularly important for adders (Edgar et al., 2010; Wrothington-Hill & Gill, 2019; House & Spellerberg, 1983; Dent & Spellerberg, 1988). Other commonly cited approaches included translocation and reintroduction (36%), public engagement and education (32%), site-specific interventions (32%), landscape-scale planning (32%), and legal protection and policy tools (30%). Genetic monitoring and rescue was mentioned least frequently (11%), primarily in studies focused on adders, reflecting the species' greater vulnerability to genetic bottlenecks (Ball et al., 2020; Pozzi, 2023).

Effective measures

Several studies identified mitigation measures that were associated with stable or recovering populations. For adders, effective actions included use of reptile-proof fencing to reduce human interference and predation, and the strategic selection of translocation sites that minimised disturbance (Nash & Griffiths, 2018; McInerny, 2019). The construction of basking banks using soil, stone and brick was also successful, with monitoring before (2017-2019) and after (2021-2022) confirming increased presence following the intervention (Pickles & Tse-Leon, 2025). Preserving summer foraging areas and migration corridors was found to support seasonal movements and reduce mortality (Julian & Hodges, 2019). In addition, whole genome sequencing revealed hidden inbreeding not detected by earlier methods, such as microsatellite markers, offering a more robust foundation for future translocation monitoring and genetic management of small, isolated populations (Pozzi, 2023).

For sand lizards, habitat management was again central to success. Maintaining structural diversity in vegetation, preserving and managing open heathland and dune systems, and enhancing habitat mosaics with bare ground, shrubs, and transitional zone were all associated with higher sand lizard densities (Edgar & Bird, 2006; Corbett & Tamarind, 1979, Graham, 2018). Sites with more varied topography and vegetation also supported more robust populations (House & Spellerberg, 1983). Effective measures also included the protection and management of egg-laying and overwintering sites, and the avoidance of large-scale tree clearance and favouring of gradual, small-scale habitat manipulation (Dent & Spellerberg, 1988). The 'Key Site' strategy for habitat protection was highlighted as a valuable framework (Edgar & Bird, 2006). Additionally, ride verges with sufficient width and sunlight exposure (at least five metres wide and with a sunshine index of ≥22 for adult activity and ≥30 for egg incubation and juvenile survival) were found to be particularly beneficial (Dent & Spellerberg, 1988).

Partially effective and mixed outcomes

Some mitigation methods showed promise but produced variable outcomes. For adders, the use of windfarms as translocation sites was assessed as a way to reduce avian predation. Though further research is needed, the results showed that the probability of avian attack was

lower at windfarm sites (1.9%) compared to control sites (5.8%) (Law et al., 2020). Where small, isolated populations are suffering genetic bottlenecks due to inbreeding, genetic rescue is sometimes used. This involves introducing genetically distinct individuals into the population to increase genetic diversity and improve population fitness (Ball et al., 2020). This approach has been proposed for the UK based on successful strategies in Swedish populations and may offer a viable option for addressing genetic bottlenecks in British adder populations (Pozzi, 2023). Public engagement campaigns, such as "Adders are Amazing!", were noted to improve awareness and tolerance, though long-term data on the effectiveness of this were limited (mention & Hodges, 2019). Protection of hibernacula and general habitat creation and management were beneficial in some contexts but not universally effective, highlighting the importance of site-specific planning (Gleed-Owen & Langham, 2012; McInerny, 2014). Some sites benefitted from practices such as appropriate grazing timing, scalloping of ride edges (creating curved bays along ride edges to increase sunny, sheltered habitat), and window creation (opening small clearings to provide basking and breeding sites), while others were negatively impacted by poorly timed or intensive interventions such as grazing and tree clearance (Gofré & Reading, 2012).

Translocation removed individuals from immediate harm, such as during construction projects, but often failed to establish viable populations. Males in particular had expanded home ranges, up to 16 times larger post-translocation, raising ethical concerns related to increased energy expenditure and predation risk (Nash, 2017; Nash et al., 2020). In one study, increased movement following translocation was associated with elevated mortality, suggesting that home range requirements must be carefully considered in mitigation planning (Nash & Griffiths, 2018).

For sand lizards, translocation was partially effective but sometimes resulted in loss of genetic diversity. In Russell (2012), reintroductions of genetically vulnerable populations showed variable viability, with modelled extinction times ranging from 5.6 to 66.2 years depending on site conditions and management. Habitat management and reintroduction efforts showed some success, but long-term viability remains uncertain due to habitat fragmentation and lack of ongoing monitoring (Moulton & Buckley, 2015). Cattle exclusion fencing was associated with higher abundance and breeding success in ungrazed areas, though the broader applicability of this remains uncertain (Reading & Jofré, 2016).

Ineffective measures

The most consistently ineffective measure for adders was translocation when implemented without sufficient consideration of habitat suitability and post-release monitoring. While it removed individuals from immediate harm, it often failed to support long-term survival or population establishment (Nash et al., 2020). Inadequate understanding of home range requirements and dispersal behaviour contributed to increased mortality and reduced effectiveness. Furthermore, translocation is not a non-expert-friendly mitigation method, it requires specialist expertise and must be carried out under a conservation translocation license issued by the relevant statutory authority (Natural England, NatureScot, or Natural Resources Wales).

For sand lizards, some dune restoration efforts were positive, but overall conservation impact was limited, and other protection measures such as restricted public access and local nature

reserve creation was not enough. In some cases, conservation efforts were deemed insufficient to counteract broader pressure such as habitat fragmentation and recreational disturbance (Jackson, 1979).

Relevance to shooting

These findings are relevant to the shooting sector, where land management practices such as vegetation clearance, ride maintenance, and pheasant release, can directly influence reptile habitat quality. One study (Jofré et al., 2016) found that sites maintaining small, multi-aged plantation mosaics, avoiding early thinning, and timing ground preparation in construction zones to avoid reptile activity supported higher reptile diversity and abundance. Young plantations aged between 3-12 years with low canopy cover (<25%) were particularly beneficial for reptile communities. For landowners and those involved in gamebird release, these results suggest that careful planning of woodland structure and ride layout can support both gamebirds and reptile conservation objectives. Avoiding ground disturbance during key reptile activity periods (March to October), and maintaining open, sunlit areas with varied vegetation, may help mitigate some of the potential unintended impacts of pheasant release and associated habitat management.

More broadly, these findings highlight an opportunity for the shooting community to align game management with biodiversity goals by adopting reptile-sensitive practices, particularly in areas known to support adders or sand lizards. Practical implementations could include voluntary seasonal restrictions on habitat work, maintaining open sunny areas, and monitoring predator impacts. Where pheasant release occurs, careful consideration of predator dynamics, vegetation structure, and disturbance levels can help reduce unintended consequences and support wider conservation objectives. By integrating these approaches, shooting estates can play a proactive role in supporting reptile conservation while maintaining sustainable gamebird management.

3.4 Recommendations for landowners and managers

The evidence reviewed highlights several opportunities for landowners and managers to support adder and sand lizard conservation through targeted, species-sensitive practices. Many of the most effective mitigation measures, such as maintaining structural habitat diversity, protecting hibernacula and breeding sites, and managing vegetation, can be integrated into existing land management regimes with minimal disruption to shooting activities.

On land managed for shooting, woodland and ride management practices can be adapted to benefit reptiles by maintaining open, sunlit areas with varied vegetation structure. Avoiding intensive ground disturbance and vegetation clearance during the reptile active season (typically March to October) can reduce direct harm and disturbance. Ride verges should be kept wide (≥5 metres) and sunny to support sand lizard activity and egg incubation (Dent & Spellerberg, 1988). Where pheasant release occurs, consideration of available food sources is important, as released birds may opportunistically peck or predate on reptiles in areas with limited natural foraging resources such as seeds, foliage and invertebrates (Dimond, 2013). Reptile fencing may be explored as an option to reduce potential predation (Law et al., 2020).

If site management includes grazing regimes, these should be planned to avoid overgrazing of sensitive habitats. Rotational grazing or cattle exclusion fencing in key reptile areas can help maintain vegetation structure and support breeding success, particularly for sand lizards (Reading & Jofré, 2016). In areas where translocation or reintroduction is considered, long-term monitoring and habitat suitability assessments are critical to ensure viability and reduce dispersal-related mortality (Nash et al., 2020).

Public engagement and education efforts, such as signage or collaboration with local nature initiatives or schools can also improve awareness and tolerance of reptiles. The shooting sector can play a leading role in promoting coexistence with such species by showcasing best practice and contributing to wider conservation goals (Julian & Hodges, 2019; Edgar & Bird, 2006).

By aligning with game management and biodiversity conservation, land managed for shooting has the potential to act as an important refuge for declining reptile species. BASC members and affiliated landowners are well-placed to implement beneficial management, demonstrating leadership in sustainable land use and contributing to national efforts to reverse biodiversity loss.

3.5 Knowledge gaps and future research

Across the evidence base, several recurring knowledge gaps were identified that limit the effectiveness of conservation planning for adders and sand lizards. The most prominent of these is the lack of long-term monitoring data, particularly following translocation or habitat management interventions. Without consistent demographic data, such as survival, dispersal, and reproductive success, it remains difficult to assess population viability or the success of mitigation efforts on a local or national level (Nash, 2017; Nash et al., 2020).

For adders, genetic vulnerability is a key concern. Multiple studies reported limited understanding of inbreeding, genetic bottlenecks, and the long-term consequences of small founder populations. There is also a need for more genomic-level data to inform translocation strategies and conservation planning (Ball et al., 2020; Pozzi, 2023). In addition, the impacts of land management practices, such as forestry operations, grazing regimes, development, and pheasant release, on adder habitat use and survival are not well understood. Public disturbance and persecution were also highlighted (although persecution is mostly historic), with calls for more research into how human activity affects adder behaviour and population trends (Gardner et al., 2019; Hodges, 2022).

Sand lizards studies similarly identified gaps in understanding long term viability of reintroduced populations, particularly in fragmented landscapes. Monitoring of translocated populations is often inconsistent, and there is limited data on how microhabitat conditions and climate variability influence breeding success (Russell, 2012; Graham, 2018). Disease surveillance and genetic monitoring were also noted as underdeveloped areas, especially in captive-bred or reintroduced populations.

For both species, broader knowledge gaps include the lack of national-scale population estimates, under-recording in remote areas, and limited integration of reptile conservation

into wider land-use planning. Methodological issues, such as detection bias, observer variability, and inconsistent survey protocols, further complicate efforts to build a robust evidence base (Julian et al., 2024; Gardner, 2019).

Despite the clear relevance of land management practices to reptile conservation, very few studies have directly assessed the potential impacts of pheasant release in relation to disturbance and predation. This represents a significant gap in evidence for the shooting sector and given the widespread releases across the country there is need to understand potential ways this could influence reptile populations, for example through habitat modification, increased predator densities (direct predation from pheasants), and human activity, and implement appropriate mitigation strategies where necessary (Law et al., 2020; Hodges, 2022).

Upcoming research, including a PhD project and an upcoming survey by the Game & Wildlife Conservation Trust (GWCT), will investigate the effects of pheasant release over the coming years. These studies are expected to provide valuable insights into how shooting practices interact with reptile conservation. However, it is important that the findings of such research are interpreted within the context of the broader threat landscape. Reptile declines are evidently driven by a complex interplay of factors, and the outcomes of these studies should not be viewed in isolation or used to attribute decline to any single factor.

Looking ahead, future research priorities reflect the full range of knowledge gaps identified across the evidence database. There is a strong emphasis on expanding long-term monitoring programmes, improving survey consistency, and developing standardised protocols. Habitat management and restoration require further evaluation to determine which practices are most beneficial under different conditions. Genetic research, including the development of SNP panels and broader genomic surveys, is needed to support population resilience (Ball et al., 2020; Pozzi, 2023). Climate change modelling and microclimate studies are also recommended to better understand emerging threats and inform adaptive management (Turner & Maclean, 2022).

Importantly, several studies call for better integration of reptile conservation into land management and policy frameworks. This includes evaluating the impacts of forestry, agriculture and development on reptile populations, and identifying opportunities to align biodiversity goals with existing land-use practices. Public engagement and education also remain key areas for future work, particularly in improving species identification and understanding (Edgar & Bird, 2006; Allain, 2020).

4. Conclusion

This Quick Scoping Review (QSR) synthesises current evidence on the threats and pressures facing adders (*Vipera berus*) and sand lizards (*Lacerta agilis*) in the UK, alongside an assessment of mitigation effectiveness. The review highlights a growing body of research since 2010, with a strong emphasis on habitat-related threats and increasing recognition of the complex interplay between ecological pressures, land management, and conservation outcomes.

The QSR process proved effective in capturing a broad and diverse evidence base, including grey literature often overlooked in traditional reviews. This was particularly valuable given the limited volume of academic research on UK reptiles. However, the review also highlighted several methodological limitations. Many studies assess multiple mitigation strategies simultaneously, making it difficult to isolate the effectiveness of individual interventions. The use of more advanced software and analytical tools could enhance quantitative synthesis in future reviews. Additionally, the reliance on a single reviewer and AI-assisted screening and data extraction could introduce potential biases, though mitigated measures were put in place through clear protocols and supervisory oversight.

Looking ahead, future research should prioritise long-term monitoring, standardised survey protocols, and improved integration of genetic, ecological, and land-use data. There is also scope to upgrade this QSR to a Rapid Evidence Assessment (REA) or full Systematic Review (SR), particularly to support policy development around gamebird release and mitigation of any potential ecological impacts on reptiles. Further QSRs could also explore related themes, such as genetic resilience, climate resilience, or multi-species habitat management.

Ultimately, this review underscores the need for collaborative, evidence-led conservation strategies that engage landowners and land-users, including the shooting community, policymakers, and researchers. By aligning game management with biodiversity goals, stakeholders across sectors can contribute meaningfully to the recovery of the UK's most threatened reptile species.

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Appendix

Screening and data extraction criteria

Table 1. Screening criteria used to determine eligibility of studies for inclusion in the Quick Scoping Review.

Screening Question	**Response Options**	**Inclusion Rule**
Is the text in English?	Yes / No / Unclear	Must be **YES** to include
Is the study based in Great Britain?	Yes / No / Unclear	Must be **YES** to include
Does the study include adders (Vipera berus) or sand lizards (Lcerta agilis)?	Yes / No / Unclear	Must be **YES** to include
Does the study discuss threats and/or pressures on adders or sand lizards	Yes / No / Unclear	Must be **YES** to include

Data extraction template

For all included studies, the following information was extracted:

1. Publication Details
- Full citation
- Publication type (e.g. journal article, thesis, report)
- Evidence type (e.g. empirical, modelled, review, grey literature)

2. Location
- Country (England, Scotland, Wales)
- County or region
- Ecosystem or habitat type(s)

3. Population
- Species included
- Were adders or sand lizards the focal species

4. Intervention (Threats and Pressures)
- Types of threats/pressures (e.g. habitat loss, climate change, predation)
- Whether threats were studied or only mentioned
- Source/driver of threat (e.g. agriculture, urbanisation, recreation)
- Severity of threat (low / medium / high / not specified)
- Temporal relevance (historical / current / projected)

5. Conservation / Mitigation Measures
- Were mitigation or management actions discussed?
- Type of actions (e.g. habitat creation, translocation, public engagement)
- Reported effectiveness (effective / partially effective / ineffective / not assessed)

6. Outcomes
- Reported population impacts (e.g. reduced abundance, local extinction)

- Any quantitative data or statistics cited

7. Knowledge Gaps and Future Research

- Were knowledge gaps identified?
- Was further research recommended?

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