A Quick Scoping Review on the Effects of Predator Control on Nature Recovery in the UK

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Executive Summary

Background and Policy Context

The control of predators in the UK is a common land management activity, especially in the context of supporting vulnerable prey species. When effective and carried out sustainably, such activities could be an essential contribution to national nature recovery targets. With the UK Government's legal commitments to halt species decline and improve biodiversity under the Environment Act 2021, predator control, whether lethal or non-lethal, may have an important role to play in protecting species of conservation concern. Evidence of the efficacy and outcomes of available control methods in the short- and long-term is pressing in the face of increasing regulatory restriction on traditional control methods and the broader societal debate about their ecological and ethical implications.

QSR Process and Methodology

This Quick Scoping Review (QSR) followed the methodology outlined by Collins et al. (2015) and assessed evidence on the effects of predator control on nature recovery in the UK. A total of 358 studies were identified through structured searches in Google Scholar and Web of Science. 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 review covered a broad range of ecosystems across the UK, including uplands, lowlands, wetlands, and coastal habitats (Section 3.2.1). Foxes, corvids, mustelids, raptors and invasive species such as American mink were the most frequently studied predators (Section 3.2.2). Prey species receiving the most attention in the literature include waders, small mammals, gamebirds, and farmland birds – many of which are species of conservation concern (Section 3.2.3). Observational studies dominated the evidence base, most of which were short-term (1-4 years), with relatively fewer experimental or long-term studies (Section 3.3.1).

Key Findings

- Lethal control methods were the most researched intervention cited in 225 studies. Trapping and shooting were the primary methods assessed, with evidence suggesting both are generally effective in reducing the presence of targeted predators and, in many cases, resulting in positive outcomes for prey species such as reduced predation pressure and increased breeding success and less than 5% having overall negative outcomes (Section 3.3.2).

- Non-lethal methods, primarily exclusion fencing and diversionary feeding, were found to be effective in specific contexts and particularly important where lethal control is illegal, not socially accepted, or practically challenging. These methods also play a crucial role in building public and stakeholder support for predator management in the context of biodiversity conservation and nature recovery (Section 3.3.2).

- Studies examining scenarios with 'no control' demonstrated that inaction often led to negative outcomes for vulnerable prey species (62% of the relevant studies), highlighting the ecological risk of doing nothing, particularly in landscapes where generalist predators dominate (Section 3.4.2)

- The majority of studies had short durations (<4 years), limiting conclusions about long-term effectiveness and impacts on predator populations or prey recovery. Long-term studies remain rare, likely due to cost and logistical issues, but are critical to improving our understanding of ecological processes and trends over time and capturing delayed or cumulative responses to predator control (Section 3.3.3.)

- Outcomes for prey species were largely positive following both lethal and non-lethal control, with waders such as curlew and lapwing especially benefiting from predator management efforts (Section 3.4.2). However, results vary depending on species, methods and local contexts.

QSR Limitations

As a QSR, this review does not include critical appraisal of study quality, however, many included studies cited limitations such as small sample sizes, observational design, or external factors, which hinder causal inferences (Section 3.3.4). Nonetheless, consistent patterns across multiple studies and contexts can still inform policy and practice as well as highlight knowledge gaps. The QSR was undertaken by one reviewer, which is not the usual recommended practice, but was necessary due to time and resource limitations. This review has not been peer-reviewed and was produced as an internal review to highlight areas for future work.

Implications for Policy, Practice, and Research

Predator control, when carried out lawfully, ethically, and in line with best practice guidance by individuals with appropriate training, should be considered a legitimate and necessary tool for supporting conservation and nature recovery goals (3.4.2). This includes both lethal and non-lethal methods alongside habitat management activities that can all be adapted to different contexts (Section 3.4.2). Individuals within the shooting sector bring vital skills, such as safe firearm use, effective trap placement, and local knowledge of species and habitats, skills that are difficult to replicate without targeted and costly training (Section 3.3.2). These contributions are central to many ongoing conservation efforts, particularly in rural and privately managed landscapes. A balanced approach is essential as not all species or habitats can recover simultaneously, and management strategies must weigh trade-offs carefully (Section 3.4.2).

Non-lethal approaches are receiving increasing interest and exploration through research and innovation, offering complementary or alternative approaches to predator management (Section 3.5.2). These methods may also provide a means for broader stakeholder acceptance and participation in predator management activities, beyond those who are familiar with shooting and trapping, and contribute to increasing public trust in these conservation strategies (3.3.2).

Evidence gaps, particularly in understanding (i) the long-term effects of predator control on ecosystem dynamics, (ii) species-specific responses to different management methods, (iii) the role of public perceptions and ethical considerations in shaping management policies and strategies (Section 3.5.1). These perspectives are essential to strengthening the efficacy and scientific robustness of predator management, expanding the available options to suit diverse contexts, and building wider public support. It is vital that the public, policymakers, and stakeholders alike recognise that predator management, whether lethal or non-lethal, is an essential tool supporting conservation initiatives, contributing directly to the recovery of vulnerable species and maintaining ecological balance in the absence of apex predators (Sections 3.4.2. & 3.5.1).

Based on the knowledge gaps identified, future research could focus on:

- Comparative evaluations of control methods in different contexts, including cost-effectiveness analysis and long-term ecological impact assessments.
- Continued development and testing of non-lethal deterrents and monitoring technologies that support broader stakeholder involvement.
- Targeted integration of predator control and habitat management and adaptive conservation planning.
- Inclusion of social dimensions to explore public and policymaker perceptions in decision-making, as well as practitioner attitudes towards different approaches.

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1. Background

Within the UK, the legal control of predators is undertaken primarily to protect and support vulnerable prey species, livestock and crops. Such control is carried out by a variety of individuals and organisations at varying scales. Predator control is common practice in the UK, particularly within the land management sector. This encapsulates a broad range of species and habitat including forests, wetlands, moorlands and farmland, comprising both public and private land. Such management is often faced with opposition, driven by differing ideological beliefs and ecological theories on how wildlife should or should not be managed.

The lethal and non-lethal control of wildlife is governed by various legislation at a national and devolved level as well as best practice guidance, developed by the relevant sector experts. There are various types of predator control carried out in the UK targeting avian and mammalian species, such as shooting, trapping, snaring, non-lethal deterrents, exclusion fencing, and diversionary feeding to name a few. The control of some species, such as certain corvids are authorised through general licences which define the purposes for which those species can be controlled in each home nation, whilst others can be managed year round (e.g. foxes and American mink).

In recent years, the laws and regulations that allow for pest control have become more restricted. For example, fox snaring was recently banned in Wales (2023) following a review of responses to the Agriculture (Wales) White Paper Consultation (https://www.gov.wales/written-statement-agriculture-wales-white-paper-summary-responses-and-welsh-government-policy), and in Scotland (2024) following the Wildlife Management and Muirburn (Scotland) Bill Consultation (https://consult.gov.scot/environment-forestry/wildlife-management-in-scotland-2023/). Responses to these consultations largely supported the ban, citing welfare concerns including the potential for inhumane practices and capture of non-target species. Other examples of increased restriction include increased restrictions within general licenses and the movement of gulls from general to individual licenses in 2019.

With a national and global biodiversity crisis progressing, the UK government has set legally binding nature recovery targets through the Environment Act 2021 (https://www.legislation.gov.uk/ukpga/2021/30/contents). This applies to all home nations requiring regulators to set commitments and meet targets such as the following which are based on DEFRA's targets and may differ between home nations:

- To protect and effectively manage 30% of England's land and sea for nature by 2030.
- To halt species decline by 2030.
  To increase species abundance by at least 10%, to exceed 2022 levels by 2042.
- To contribute to environmental, economic and social improvements such as carbon capture, flood management, clean water, clean air, healthy soil, pollination, and recreation.

Conservation organisations and land managers contribute greatly to the above targets across the UK, and predator and pest management can play an important role in achieving these goals. Despite this, effective management methods, such as snaring, are often perceived in a negative light for emotive reasons, or ethical concerns of target and non-target species sometimes based on out-of-date practice. As a result, there is a risk of criticising and restricting methods based on ideology and public perception of shooting, with knock-on effects to associated management. It is therefore vital that decisions regarding predator management are evidence-based.

Evidence of the effects of predator control on nature recovery appears to be mixed with some studies contradicting one another. Furthermore, literature and evidence reviews on this topic tend to focus on specific species or habitats, and most of those included in this QSR were produced prior to 2020. Therefore, the synthesis of an up-to-date robust evidence-base is required to inform potential future policy and best practice guidance.

The primary focus of this quick scoping review is to draw together an overview of evidence from peer reviewed and grey literature on the topic of predator control and nature recovery in the UK and discuss the key developments in policy and practice in relation to this. The review sets out to identify the quantity and characteristics of the current evidence-base and highlight any knowledge gaps that require further research. The findings of the review will help guide future research, policy decisions, and best practice guidance around predator control, ensuring a balanced evidence-based and proportionate approach to any necessary changes.

1.1 Project Aims and Objectives

This project took the form of a Quick Scoping Review (QSR), to collate evidence from peer-reviewed and high-quality grey literature on the effects of predator control on nature recovery in the UK. The findings from this project will be used to influence predator control policy decisions and highlight knowledge gaps, providing a foundation for further research.

1.1.1 Objectives

The objectives of this project are:

- To undertake a QSR to list and outline academic research and high-quality grey literature on the effects of predator control on nature recovery in the UK.
- To outline the different types of predator control that have been studied and the species and ecosystems these practices relate to.
- To review and outline the overall outcomes of different types of predator control (including lethal, non-lethal, biological control, and no control), on relevant predator and prey species and the implications for nature recovery.
- To link these findings to current policy and potential future policy as well as the UK governments nature recovery goals.
- To outline the evidence gaps and provide implications of these in relation to policy practice, and further research.

1.1.2 Research Outputs

The outputs of this report will be:

1. A QSR outlining the quantity and characteristics of the academic and grey literature evidence base on the effects of predator control on nature recovery, the different types of predator control and their outcomes for the relevant species and habitats, and how this relates to policy decisions.
2. Implications of the findings and areas that require further research, that could be addressed in future projects either internally or externally.

2. Methodology

This report was produced following DEFRA guidelines on Quick Scoping Reviews and Rapid Evidence Assessments (Collins et al., 2015). The QSR in this report aims to provide an initial scoping of the evidence base for the effects of predator control on nature recovery in the UK.

A QSR is a type of systematic evidence review used to quickly understand the impact or pressure of a policy intervention by providing a snapshot summary of the available literature (Collins et al., 2015). It aims to provide clear and informed conclusions on the volume and characteristics of an evidence base and generally requires fewer sources and less time than a Rapid Evidence Assessment (REA) or full systematic review. The QSR is therefore restricted to a narrower selection of sources which can be identified, screened, and evidence extracted in the shorter timeframe available. Due to time and access constraints, this review only searched two 'libraries' and therefore may not be exhaustive.

A QSR does not include a critical appraisal of the evidence, therefore there may be variations in the relevancy and robustness of the studies that have not been included in the scope of this report (Collins et al., 2015). The limitations of this QSR methodology are discussed in Section 2.3.4 below.

The evidence will be described in terms of their volume and characteristics. Themes present across the literature will be identified and the evidence related to those themes described to indicate what the evidence shows in relation to the research question, what this implies for policy and best practice guidance, and areas that require further research to fill knowledge gaps.

2.1 Conceptual Model

The conceptual model below (figure 1) illustrates the overall policy and practice contexts and interactions which the QSR aimed to investigate.

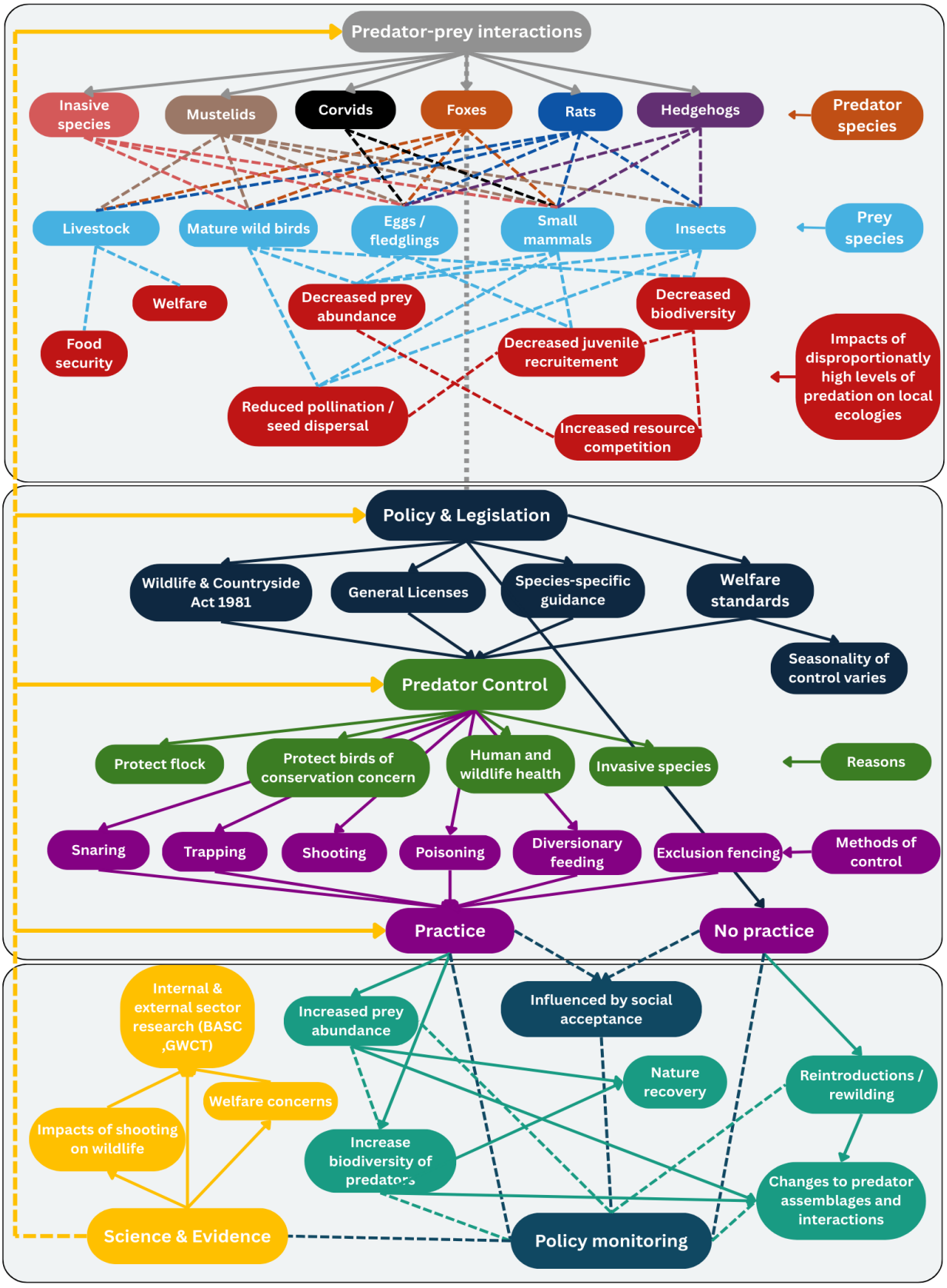
Predator-prey interactions
Inasive species
Mustelids
Corvids
Foxes
Rats
Hedgehogs
Predator species
Livestock
Mature wild birds
Eggs / fledglings
Small mammals
Insects
Prey species
Welfare
Decreased prey abundance
Decreased biodiversity
Food security
Decreased juvenile recruitement
Impacts of disproportionatly high levels of predation on local ecologies
Reduced pollination / seed dispersal
Increased resource competition
Policy & Legislation
Wildlife & Countryside Act 1981
General Licenses
Species-specific guidance
Welfare standards
Seasonality of control varies
Predator Control
Protect flock
Protect birds of conservation concern
Human and wildlife health
Invasive species
Reasons
Snaring
Trapping
Shooting
Poisoning
Diversionary feeding
Exclusion fencing
Methods of control
Practice
No practice
Internal & external sector research (BASC ,GWCT)
Increased prey abundance
Influenced by social acceptance
Nature recovery
Reintroductions / rewilding
Welfare concerns
Impacts of shooting on wildlife
Increase biodiversity of predators
Changes to predator assemblages and interactions
Science & Evidence
Policy monitoring

Figure 1. A conceptual model of the policy context around predator control practices. The model highlights the interactions between predator and prey groups and the potential negative impacts of predation on prey species if there are disproportionately high levels of predation (e.g. in the absence of predator management). It then links predators to policy and legislation, which through welfare standards and evidenced reasons for implementation of predator control, determines which species can be managed and through what methods. These practices, or no practices in the case that species are protected, are linked to potential impacts and outcomes for wildlife and nature recovery but are also influenced by social acceptance. These impacts and outcomes, and the policies guiding them, are monitored which in turn highlights knowledge

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 effects of predator control on nature recovery.

Table 1. Table demonstrating the PICO elements of the primary research question 'What are the effects of predator control on nature recovery' (based on the methods of Collins et al., 2015).

PICO Element	QSR Element
Population	Predators, scavengers
Intervention	Use of predator control/management methods (lethal and non-lethal)
Control	No control or alternative approaches including reintroductions and habitat management
Outcome	Effects on nature recovery (prey abundance, productivity, juvenile recruitment, competition, survival, biodiversity)

The PICO method is used to help define the questions addressed in the review and the possible outcomes of a particular policy approach. Two approaches are considered in this QSR (1) the use of predator control (lethal or non-lethal) compared to (2) no control or alternative indirect methods.

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

- Geographical reference: United Kingdom, Ireland and British Islands
- Climatic conditions: Temperate
- Language: English
- Population restrictions: Native and non-native currently extant in the UK, reintroduced species and proposed species for reintroduction.
- 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 sections 2.3.1 and 2.3.2 below)

2.2.1 QSR Research Questions

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

Primary research question:

- What are the effects of predator control on nature recovery in the United Kingdom?

Secondary questions:

- What are the different types of predator control implemented?
- Is the overall outcome influenced by the type of predator control?
- Is the overall outcome influenced by the predator species being controlled?
- What are the overall outcomes of no predator control (or other indirect alternatives such as habitat management and reintroductions)?
- What do these findings indicate in the context of evidence-based policy decisions?
- What are the evidence gaps, and which of those need to be filled to inform policy?
- What are the implications for future work and research on predator control in relation to nature recovery goals in the UK?

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.

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 all predator species and control methods produced very broad results, in excess of 100,000. 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.

The top 200 hits from each search - where that many were presented - totalling 3,623, were compiled into an Excel spreadsheet. The scope initially included research in European countries where the species and environment are comparable, however, due to the volume of results, it was agreed by the research group to only include UK studies at the screening stage. The results were

screened first by title, ensuring they were relevant to research questions 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 abstract and full text. After screening was complete, 234 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 results produced from these tests ranged from 240 to 46,000. The string for the actual search was decided and produced 15,851 results. These results were then refined by exclusion criteria related to (1) topic area/category, (2) country, (3) meso- and micro- citation topics, and (4) research area. 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 total of 333 results were then screened by title, abstract and full text, and any duplicates were removed. This resulted in 124 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
"predat*"	"predator control*"	"nature recovery"
"scavenger"	"management"	"biodiversity"
"mesopredat*"	"lethal control"	"prey abundance"
"red fox"	"cull*"	"productivity"
"American mink"	"trap*"	"juvenile recruitment"
"rat"	"shooting"	"rewild*"
"carrion crow"	"snar*"	"naturalisation"
"corvid"	"predator removal"	"UK"
"magpie"	"non-lethal control"	"United Kingdom"
"rook"	"exclusion fencing"	"Britain"
"jackdaw"	"deterrent"	"conservation"
"mustelid"	"reintroduc*"	"restoration"
"stoat"	"habitat management"	"wildlife management"
"weasel"		"breeding birds"
"polecat"		"small mammals"
"pine martin"		"ecosystem"
"badger"		
"hedgehog"		
"grey squirrel"		
"raptor"		

"gull"		

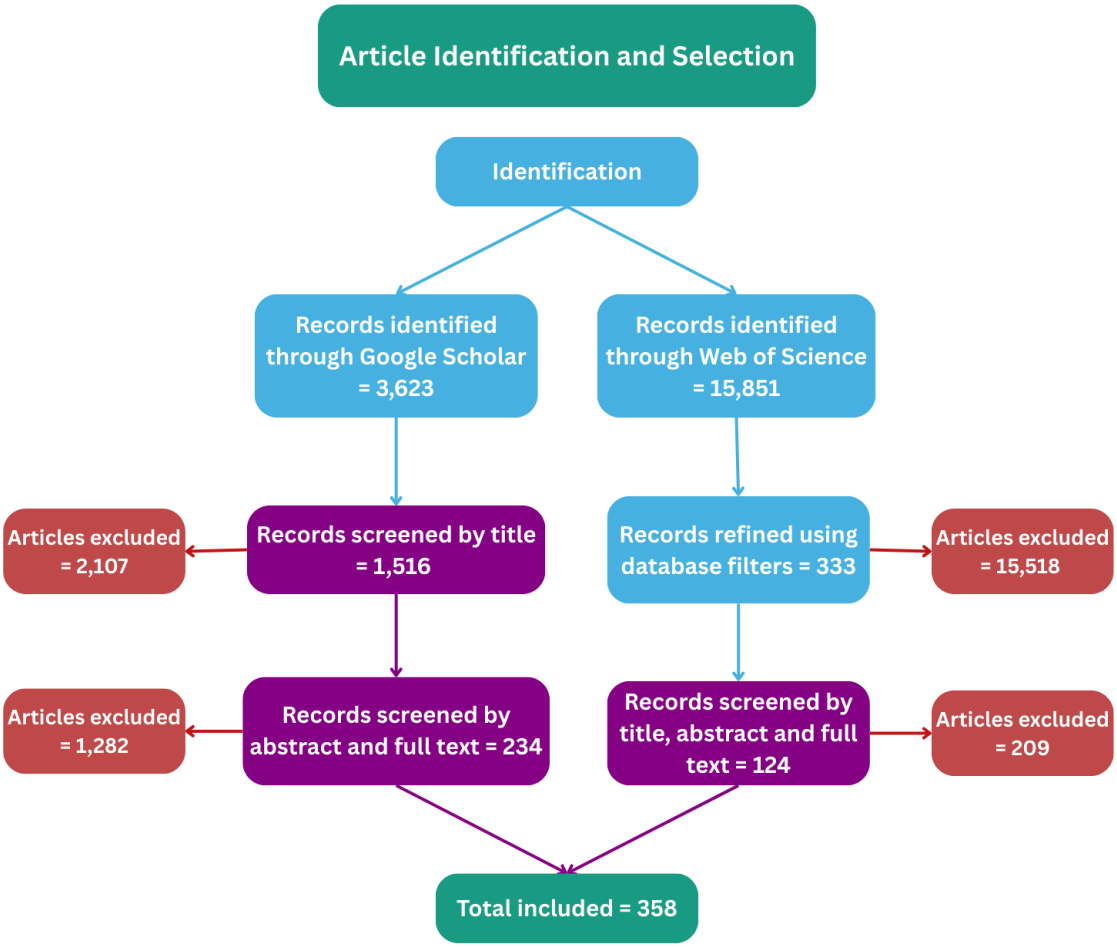

Figure 2. Flow diagram of the screening methodology and number of papers included and excluded at each stage.

2.3.3 Review methodology

An Excel spreadsheet containing 236 results from Google Scholar and 124 results from Web of Science was populated with columns for data collection. These were designed to capture key pieces of information from each document. Due to the number of outputs and time-resource constraints, the use of Artificial Intelligence (AI) was tested to determine the efficacy of using it to extract relevant pieces of information from each document by providing it with clear and specific instructions based on the protocol of this QSR. After testing this with different wording and formats, it was determined that this method would significantly reduce the time needed for the

reviewer to extract information as opposed to reading each document or using key word searches within the documents. Information was extracted and organised in an excel sheet. A breakdown of this can be found in Appendix: Data table headings.

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 which also require institutional access. Additionally, time constraints inherent in a QSR limit the level of detail that can be extracted from each study, especially given the wide scope and large volume of studies retrieved. 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 evidence extraction process introduces an additional layer of uncertainty, as the efficacy and potential biases of such tools are not always easily identifiable.

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, species, intervention types, or research methods, leading to overlap in reported results. Additionally, some studies discussed interventions rather than directly implementing or measuring them (e.g. theoretical modelling, reintroduction planning, or observation studies where predator control occurred but was not directly measured). 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

3.1 Evidence base characteristics

The QSR reviewed 358 pieces of evidence (Figure 2). The evidence base was made up of 277 peer reviewed journal articles, bulletins and short reports with the remainder being grey literature (n=81), including book chapters, postgraduate theses, conference papers and proceedings, evidence reviews, and reports such as those produced by Defra, Natural England, and RSPB.

The geographical distribution of these studies across the UK is dominated by evidence from England (n=157), followed by Scotland (n=102), with evidence from Wales appearing in 37 pieces of evidence. Studies conducted in Great Britain and the United Kingdom as collective study regions each contributed 39 and 41, respectively. The remaining 28 studies were from Northern Ireland (n=13), Ireland (n=8), British Islands (e.g. Uist, Outer Hebrides, Shetlands, Jersey, Isle of Man) (n=5). The remaining two studies are conceptual with a global context.

The majority of evidence was from the 2015-2019 period (n=72), with the evidence base growing rapidly from the mid-1990s to 2020s (Figure 3). No evidence was found for years prior to 1970.

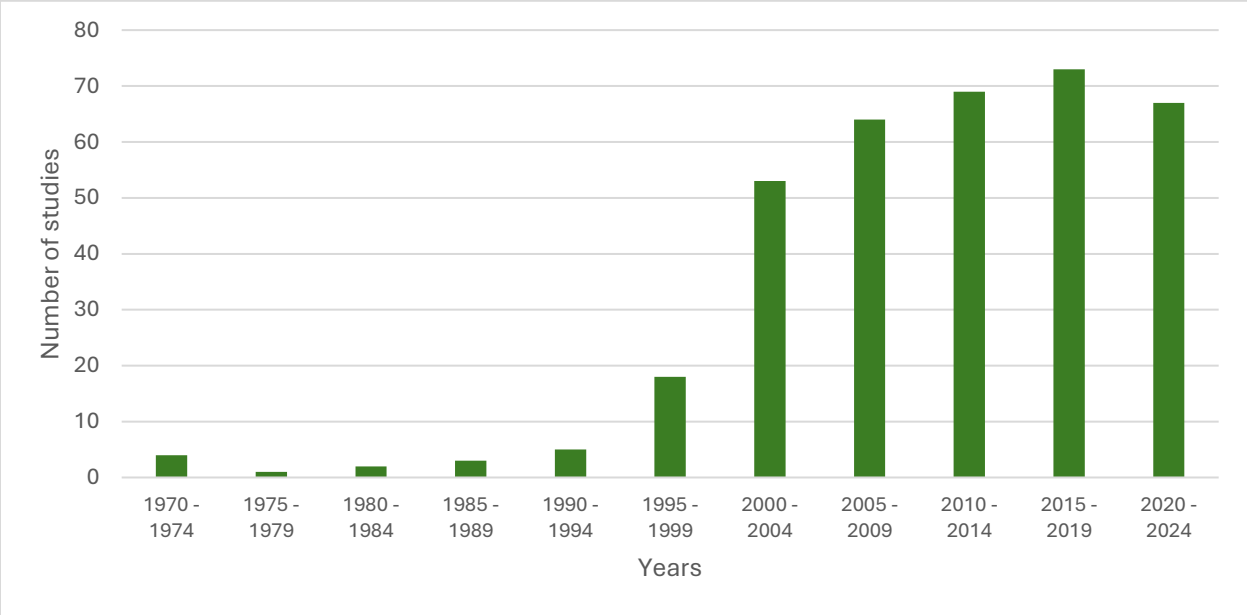

Figure 3. The temporal distribution of the evidence database over a 54-year period (from 1970 to 2024). Years are grouped at intervals of 5 years.

The distribution of studies is broadly representative of the home nations and is therefore likely representative of the species and habitats reviewed in this QSR. This allows for broader geographic conclusions about the themes of the findings of this review.

However, it is important to note that studies conducted on islands were generally focused on controlling populations of invasive/non-native species to protect ground-nesting birds. Such

studies are not always comparable to UK mainland ecosystems, and control methods can be much more effective on islands where recolonisation is less likely to occur. Furthermore, species such as hedgehog are considered invasive on islands but are a protected on the mainland. Most of the species controlled on islands, and the species they impact are not part of the key predator and prey groups identified below (3.2.2 and 3.2.3) and therefore do not greatly influence these results.

3.2 Subject Matter

3.2.1 Ecosystems and Habitats

Studies were undertaken in a broad range of ecosystems. Woodlands and lowlands (including dry grasslands, farmland, scrubland, and hedgerows) each appeared in 37% of the database. Another frequently studied ecosystem was the uplands, appearing in 34% of the database. Lowland wetlands (25%) and coastal margins (19%) appeared less frequently, and a total of five pieces of evidence did not have clearly defined ecosystem features and could therefore not be categorised accurately.

Although the categorisation is not exactly the same, based on proportions provided by the Habitat extent and condition, natural capital, UK: 2022 environmental account, the above percentages are broadly representative of the UK's habitat composition with lowlands and woodlands making up the majority, and coastal margins making up the smallest proportion (Office of national statistics https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/habitatextentandconditionnaturalcapitaluk/2022).

However, uplands and wetlands appear to have a disproportionately high representation in the database. Both uplands and wetlands are important breeding sites for many species such as waders and other ground-nesting species of conservation concern, which may result in higher research efforts. For uplands, this may also be explained by shooting on grouse moors which faces opposition both in relation to predator control and habitat management strategies such as heather burning. These sites are often managed by grouse moor managers and wildfowling clubs, therefore further research on such sites is pertinent to understanding the conservation value of land managed by the shooting community.

3.2.2 Predator Species

Key predator groups that appear to be most studied in relation to predator control or predation impacts on prey species have been identified. Red fox (*Vulpes vulpes*; n=185), corvids (*Corvus spp.;* n=154), and native non-domesticated mustelids (e.g. stoats, weasels, pine martens, badgers; n=125) were the most frequently studied predators in the database, with raptors (e.g. buzzards, hen harriers, red kites) and invasive species (including American mink, grey squirrel, and ferrets) also occurring relatively frequently (n=96 and n=79, respectively; figure 4).

It's important to note that rats (*Rattus spp.*) and hedgehogs (*Erinaceus europaeus*) were considered invasive species in studies taking place on islands (rats n=9, hedgehogs n=2, both n=2) but these are not included in the invasive species category as they are not invasive on the mainland, which is the main focus of this QSR.

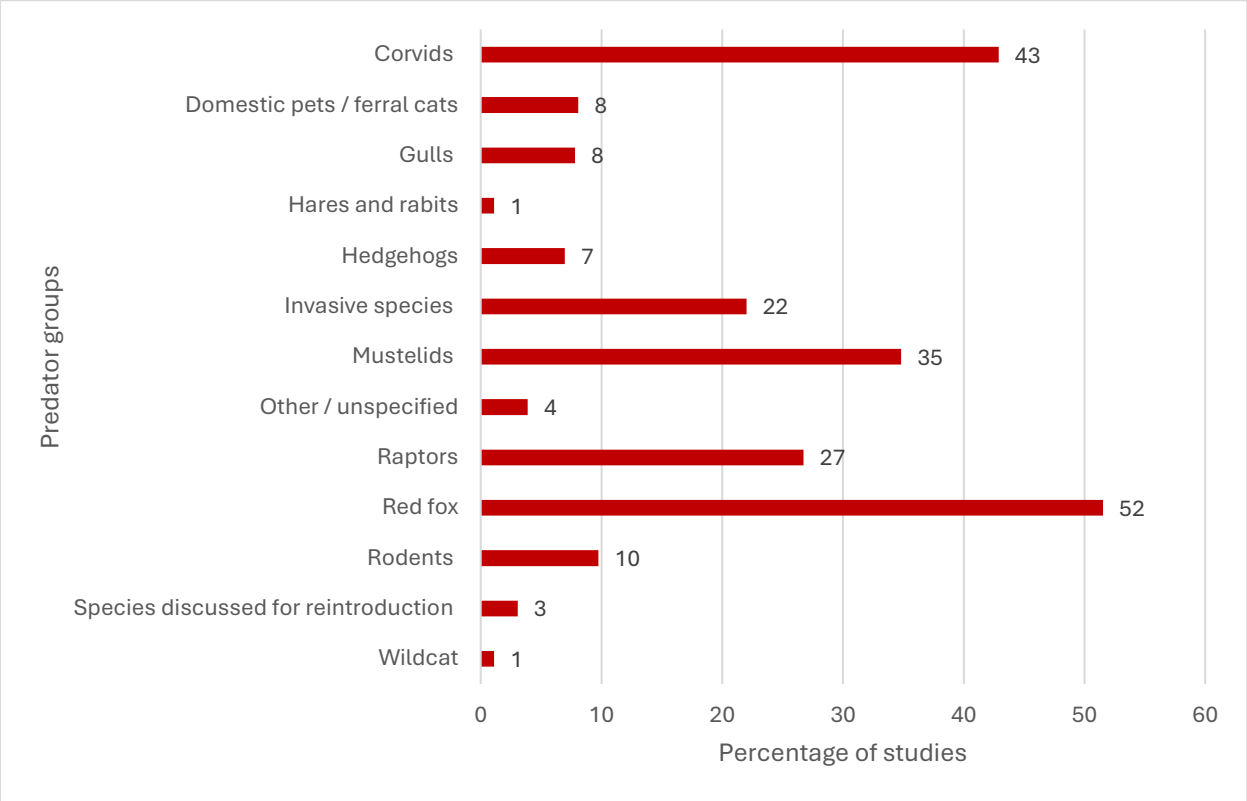

Figure 4. Percentage of occurrences of each predator category in the evidence database. Note that percentages do not sum to 100% because many studies investigated multiple predator species.

Matthews et al. (2018) estimated the total population size of most mammalian predator species in the UK. Considering these estimates alongside the proportion of the QSR database of studies, it is evident that the proportion of studies on mammalian species are not proportional to the abundance of those species in the UK. For example, brown rats (n=7,070,000), grey squirrels (n=2,700,000), hedgehogs (n=522,000) and native mustelids such as badgers (n=760,000) and stoats (n=483,000) each have higher population estimates than red foxes (n=357,000). Therefore, the large proportion of fox studies in the database is not proportional to the species' abundance and is likely more representative a higher research interest potentially due to their generalist hunting strategy and lack of an apex predator, giving them a greater capability to impact a wider range of species across various ecosystems. The proportions of species represented in the database are also likely influenced by legislation on the control of some species being more restricted than others, and those that cannot legally be managed are less likely to appear in the database.

Spatial distribution of predator studies

The previously identified five key predator groups (see section 3.2.2) are widely distributed across UK ecosystems, with all having been studied in each ecosystem type. For generalist predators such as foxes and corvids, this likely reflects their ecological flexibility and broad habitat use. For other groups - native non-domesticated mustelids, raptors and invasive species – their widespread study most likely reflects the diversity of species and specialisms within each broad species group. Gulls are also included here due to their relevance in certain management practices, particularly those involving licensed removal. Whilst rodent studies (n=35) appeared slightly more than gull studies (n=28), nearly a third of these were in relation to island ecosystems and are therefore not discussed in detail here. However, it is worth noting that rodents were also studied in all ecosystem types reflecting their adaptability. The distribution of studies across habitat types for each predator group is summarised in Table 2.

Table 3. The percentage of key predator group studies of the total number of studies in each habitat type. Note that total column and row percentages may exceed 100% because many studies investigated multiple predator groups, sometimes across multiple habitat types.

Habitat type	Fox studies	Corvid studies	Mustelid studies	Raptor studies	Invasive predator studies	Gull studies
Uplands (n=123)	66	59	29	35	18	7
Lowlands (n=135)	59	51	38	29	17	4
Lowland wetlands (n=88)	58	44	34	22	42	11
Woodlands (n=134)	45	33	42	31	26	2
Coastal (n=67)	27	19	15	9	39	28
Other / not clearly specified (n=5)	20	40	20	0	40	0

Foxes and corvids are the most frequently studied predator groups and are recorded across a diverse range of UK habitats. Their prevalence in upland and lowland studies likely corresponds with the presence of vulnerable prey species, such as such as ground-nesting birds (e.g. waders and grey partridge), in these habitats. Foxes, in particular, receive substantial research attention in lowland wetlands and woodlands, with fewer studies in coastal areas, a pattern that aligns with both their habitat preferences and potential impacts on species within those habitats. Of the 186 fox studies, 119 also included corvids, underscoring the shared ecological roles these two generalist predators play. Their adaptability, widespread distribution, and absence of natural predators (in the case of foxes) highlight their significance across UK landscapes and the potential broad-scale threat they may pose to vulnerable prey species if left unmanaged.

Mustelids studies show a contrasting pattern, with most research focused on woodlands and lowland habitats, though they are occasionally featured in upland and lowland wetlands studies (Table 2). This distribution reflects the diversity and habitat specialisation of species within this broad group. For example, pine marten are woodland specialists whilst badgers favour areas that are ideal for digging burrowing systems across a wider range of habitats (e.g. woodlands, grasslands, farmlands. Stoats and weasels are more generalist in their habitat use but differ in prey preference, with weasels primarily preying on small rodents and stoats often targeting rabbits. Given these ecological differences, generalisations across the mustelid group are limited.

Raptors are studied relatively evenly across most habitat types, with the exception of lowland wetlands (Table 2). Like mustelids, this evenness reflects the ecological range of the group, encompassing both specialists (e.g. hen harrier, merlin, and sparrowhawk) and generalists (e.g. common buzzard, red kite, and kestrel).

Invasive species are most frequently studied in wetlands and coastal areas (Table 2), a trend likely driven by research on American mink which are unique in their ability to hunt in terrestrial and aquatic environments.

Finally, gull studies are concentrated in coastal habitats, though several studies are also conducted in lowlands and uplands (Table 2). This distribution likely reflects the increasing adaptability of some gull species and their interactions with human-modified environments such as urban areas and farmland (Spelt et al., 2022).

3.2.3 Prey Species

Understanding the current evidence on the impacts of predator control on nature recovery requires examining which prey species are most frequently studied in relation to predator control and predation. The species in the database vary in abundance, habitat use, and vulnerability to predation, factors that likely influence the research focus and effort.

Waders appeared most frequently in the database (n=129), with lapwing being the most studied prey species occurring in 70% of wader studies. Small mammals (n=117), gamebird quarry species (n=105), and songbirds/farmland birds (n=77) were also frequently studied.

The high proportion of studies on waders and small mammals likely reflects the conservation concern surrounding several species in these groups, such as lapwing (*Vanellus Vanellus*), curlew (*Numenis arquatat*), and water voles (*Aricola amphibius*), which are classified as 'Near Threatened' or 'Endangered' (Brown et al., 2015; BirdLife International, 2021). Songbirds also receive noteworthy research attention likely due to long-term and steep declines in many species (Thomson et al., 1998; Dunn, 2009). In contrast, the prominence of gamebird studies is likely driven by low numbers of native grey partridge, whilst the remainder is likely influenced by the role of

predator control in gamebird management and interests related to shooting (Ewald et al., 2020; Rantanen et al., 2010).

Studies on medium and large mammal prey species are low in number, largely due to the absence of apex predators in the UK such as wolves, lynx and bears. The absence of such species has allowed for mesopredator release, whereby medium-sized animals such as foxes, mink and badgers are able to increase in abundance largely unregulated by natural predation (Roemer et al., 2009; Lozano et al., 2013). As a result, ecosystems in the UK now require human-mediated

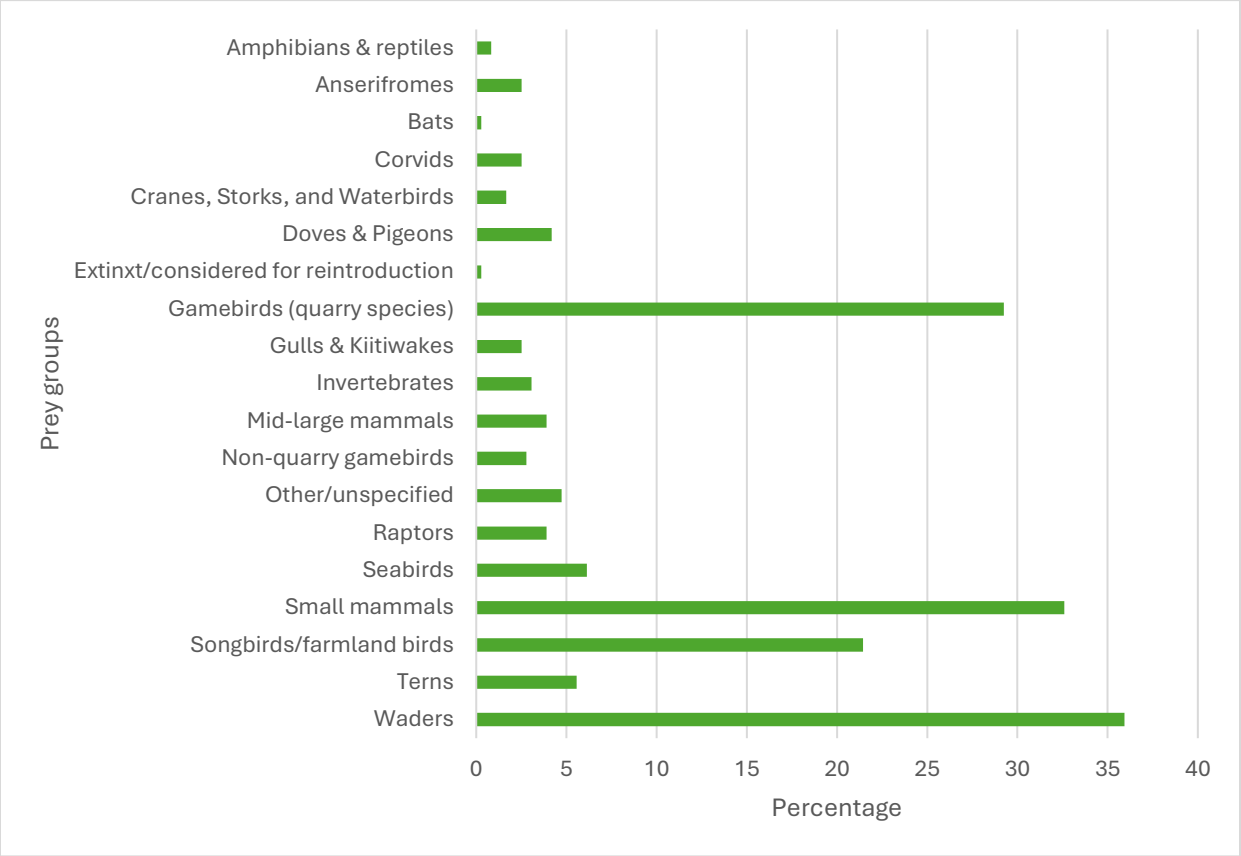

Figure 5. The percentage of occurrences of each prey category in the evidence database. Note that percentages do not sum to 100% because many studies investigated multiple prey species.

predator control to mimic the regulatory role that apex predators would otherwise play in maintaining ecological balance (Roemer et al., 2009).

Prey species associated with key predator groups

The key predator groups discussed in the previous section (3.2.2.) are discussed here in relation to their associated prey species. The most studied prey groups were waders, gamebirds, farmland birds, and small mammals (Figure 5). Therefore, the focus of this section is on these groups. It is also important to note that, as several predator and prey species often co-occur within the same studies, these associations may not always represent direct interactions with each individual predator studied.

Waders were the most frequently studied prey group across all predator types. Among the predator groups foxes were the most frequently studied in relation to waders (n=92), highlighting their widespread influence on ground-nesting birds. Corvid studies also often focused on waders (n=86), consistent with their foraging in open, agricultural and wetland habitats. Native mustelids were another significant predator group linked to wader studies (n=47), reflecting the role of some species in this group, such as stoats and weasels, in nest predation. Raptors (n=30) and invasive predators (n=21) were studied less often in relation to waders, though still noteworthy. Gull studies also primarily focused on their effects on waders (n=14), reflecting their coastal overlap with these species and potential for both predation and competition in breeding areas (Alfrawi, 2020; Parr, 1993).

Gamebirds were another key prey group examined across multiple predator types. Foxes were most frequently associated with studies on quarry gamebirds (n=80), reflecting concerns about the impacts of predation on gamebird populations managed for shooting. Corvids were also often studied in relation to gamebirds (n=61), again reflecting their presence in agricultural landscapes, often overlapping with foxes. Raptors and mustelids were also linked to gamebirds in a substantial number of studies (n=50 and n=32, respectively). Invasive predators were less frequently mentioned (n=14), reflecting the difference in habitat use and choice of prey for species in this group (e.g. American mink and grey squirrels).

Studies on small mammals were most frequently associated with mustelids (n=40), reflecting the specialist hunting behaviour of some species in this group, particularly stoats and weasels. Foxes were also often studied in relation to small mammals (n=42), consistent with their generalist diet. Invasive predators appeared in the same number of studies (n=42), highlighting their recognised impact on native mammal populations (Fraser et al., 2015; 2017; Auld et a., 2019). Raptors also received substantial research attention (n=29), reflecting the diverse diets within this group. Corvids were mentioned less often in relation to small mammals (n=14), likely due to their opportunistic feeding behaviour focusing more on avian prey and scavenging.

Farmland birds were most frequently linked to corvids (n=49), likely due to their shared presence in agricultural landscapes (Thomson et al. 1998; Capstick and Madden, 2021; Capstick, 2018; Madden et al., 2023). Foxes also appear to be regularly associated with this group (n=35), again reflecting their generalist nature, although this may be influenced by their co-occurrence with corvids in studies set in agricultural landscapes. Raptors featured similarly (n=28), again reflecting the varying diets and mix of specialist and generalist predators in this group. Despite some mustelid species being present in farmland landscapes, this group were studied less frequently in relation to farmland birds (n=19), likely reflecting their prey preferences often targeting small mammals and the eggs of ground nesting birds. Invasive predators were also less often linked to farmland birds (n=17), suggesting some level of predation impact but less than other prey groups.

Studies involving gulls reported interactions with seabirds (n=9), terns (n=9), and other gull species and kittiwakes (n=4), typically in the context of intraguild predation. This reflects the gulls'

role as both predators and competitors in coastal and seabird colony settings (Alfarwi, 2020; Robertson et al., 2015; Finney et al., 2001; 2003; Thomas, 1972).

These results highlight key species in the UK that may be disproportionately affected by predation in the absence of apex predators or predator control, particularly ground-nesting birds such as curlew, lapwing and grey partridge. Many of these species are already in decline due to habitat loss, agricultural intensification, and climate-related pressures, making them especially vulnerable to increases in predation pressure (Baines et al., 2023; Ludwig et al., 2019). In the absence of top predators, generalist mesopredators like foxes, corvids and some mustelids have the potential to exert greater pressure on these populations through nest predation or chick mortality for example (Roemer et al., 2009; Lozano et al., 2013). Such pressures are particularly damaging, especially to those with already low populations, as this can lead to reduced juvenile recruitment which can be a major barrier to population growth. This is because consistently low juvenile recruitment does not allow an adequate offset of new young to account for adult mortality.

Small mammals, particularly voles, mice, and shrews, also play a key role in UK ecosystems as prey for raptors and mustelids, but also as seed dispersers. Invasive species such as American mink have been shown to significantly reduce small mammal populations in some habitats, and localised over-predation may hinder recovery, particularly in lower quality or fragmented landscapes (Fraser et al., 2015; Robinson et al., 2013). Lower species abundance and sustained pressure on juvenile recruitment in small mammals can disrupt population dynamics and reduce prey availability which may then have knock-on effects on specialist predators such as barn owls, potentially resulting in further ecological imbalances or increased pressure on alternative prey species such as birds.

Monitoring predator abundance and distribution in relation to species of conservation concern is therefore essential. Such monitoring can allow for identification of predation risk 'hotspots' enabling more targeted and evidence-based approaches to predator management for conservation. Continued research over different spatial and temporal scales can also provide critical insights into broader ecological functions of recovering landscapes, ensuring that conservation interventions address not only species-specific needs but also the trophic interactions that underpin nature recovery.

3.3 Study Design and Implementation

3.3.1 Study Design

The study designs in the evidence database have been broadly categorised into nine groups, there are: conceptual/theoretical, modelling, literature and evidence reviews (including meta-analyses), observational, case studies (field or analysis of multiple), experimental, longitudinal (long-term studies), social science studies and other.

The majority of studies used observational methods (n=200), followed by literature/evidence reviews (n=79) (although these may capture results from other studies included in this review)

and experimental studies (n=75). Longitudinal studies (n=57), which track changes over time, were less frequent but made a noteworthy contribution to the evidence base, considering the resources required for such research. Modelling approaches were used in 33 studies, while conceptual/theoretical studies (n=12), case studies (n=7), social science studies (n=9) appeared less frequently. The 'other' category consisted of three studies: one using a cost-effectiveness analysis, another assessing conservation status of bird species, and the third based on proceedings from a workshop discussion that featured presentations by researchers.

3.3.2 Predator Control and Conservation Management Practices

Control and management practices have been grouped into four broad categories:

1. **Lethal control**, such as shooting, trapping and snaring (the latter two often followed by shooting).
2. **Non-lethal management**, including exclusion methods, diversionary or supplementary feeding, nest disturbance and destruction, and habitat management aimed reducing predation or enhancing prey habitat.
3. **Reintroductions**, and **indirect biological control**, where reintroduced species (e.g. pine marten) influence predator-prey dynamics. This category also includes targeted reintroductions, such as the grey partridge, as a conservation intervention.
4. **No intervention**, where a species cannot be legally managed, natural predation is observed, or scenarios without an intervention are compared to lethal or non-lethal management methods.

Lethal control methods were researched or mentioned in 225 of the 358 studies, making them the most frequently cited management practice in the database. Non-lethal management appeared in 120 studies, while reintroductions or biological control represented a smaller proportion of the database (n=34). Studies involving no intervention (n=111) were nearly as common as those involving non-lethal management.

Among the studies categorised as 'no intervention', 29 compared outcomes to lethal control, nine to non-lethal interventions, and ten compared no intervention to both lethal and non-lethal interventions. The remaining 63 studies comprised of dietary or predation studies, mostly on species that cannot be legally controlled.

Lethal Control Methods

It can be assumed that for commonly controlled predators there are standard methods of control used. For example, foxes are primarily controlled by shooting, or snaring then shooting, and corvids are usually controlled by trapping and shooting or directly shooting, often under license. For native mustelids, stoats and weasels are primarily killed in approved 'kill traps' whereas invasive species, predominantly American mink and grey squirrel, are normally trapped used live-capture traps and then shot. Grey squirrel are also occasionally caught in kill traps or shot directly at feeders.

Trapping is the most frequently studied method of lethal control cited in the literature, appearing in 128 of the 358 studies. In the review process, no distinction was made between live-capture and kill traps, therefore it is assumed that the relevant methods for each species outlined above applies. Shooting is also widely studied (n=86), while poisoning (n=14) and snaring (n=12) were far less frequently reported.

It is likely that the representation of trapping and shooting within research aligns with their legal status and widespread use for various species in the UK, whereas snaring and poisoning are more species-specific methods usually only applicable to foxes and rats, respectively, with both also facing opposition regarding ethical concerns, and broader ecosystem impacts in the case of poison. In light of recent changes to legislation banning snare use in Scotland and Wales, and changes to rodenticide use UK-wide (Agriculture (Wales) Act, 2023; Wildlife Management and Muirburn (Scotland) Act, 2024), the potential for future research on these methods may become limited and may also influence researchers' willingness to study them. Further research could explore whether public attitudes do influence the extent of research on different control methods and whether it influences the actual methods chosen by different land managers (e.g. game management contexts compared to conservation organisations).

Target species of lethal methods

In many papers the method of control is not clearly attributed to individual species. Most studies included multiple species, meaning that shooting or trapping may not have been directed at all species reported in a study. For instance, while raptors appeared in some studies assessing shooting, this method was not directed at them, as lethal control of raptors is illegal in the UK. Consequently, raptors and other protected species (e.g. badgers and pine marten) are not discussed further in this section.

Among studies investigating trapping, foxes appear to be the most frequently targeted species (85%), however this is likely a result of co-occurrence of foxes in many corvid studies which are often trapped and then shot. Therefore, this method also occurs in many corvid studies (69%), followed by mustelids (42%) and invasive species (21%). Similarly, among studies investigating shooting as a control method, corvids were included in 69% of studies, foxes in 73%, mustelids in 36%, and invasives species in 18%. These distributions largely reflect the species representation within the overall database.

Due to the overlap of species within studies and the lack of data extracted for species-specific control methods, it is difficult to determine which methods have been most extensively studied for each species. Further research on this could imply whether the choice of control method for each species is most influenced by policy, public perceptions, or practicalities of controlling different species in varying habitats.

However, it is evident and expected that foxes and corvids are highly represented in studies on lethal control, which is likely a reflection of their adaptability and therefore widespread distribution across the UK. The association between these two species groups and waders in the database is

indicative of their perceived negative impact on wader species, several of which are steeply declining with 'Near Threatened' status (Brown et al., 2015, BirdLife International, 2021). In the mustelid group, species such as pine marten and badger are protected and smaller mustelids such as stoats and weasels may be considered less of a priority in comparison to the widespread generalist predators discussed above.

Nonetheless, the findings indicate that less studied methods such as snaring require more attention in research which would enable more balanced decision making regarding the efficacy of control methods for specific purposes. Exploration of non-lethal methods is also vital to improving the options available for land managers, especially where lethal control is restricted or controversial.

Non-lethal Management Methods

From the 120 studies on non-lethal predator management, six main control methods were identified: exclusion fencing, diversionary feeding, nest or den destruction, deterrents, and habitat management.

Among these, exclusion fencing (n=32) was one of the most frequently researched non-lethal methods, while diversionary feeding (n=17), deterrents (n=9), and nest or den destruction (n=5) were studied less often.

Habitat management as an indirect predator control strategy

Changing or managing the habitats on a site can substantially alter its attractiveness and accessibility for both predators and prey. As many studies broadly referenced habitat management interventions, such as agri-environment stewardship schemes or as part of gamebird management, this category has been split into two:

1. **General habitat management interventions** (n=68) – Studies either did not directly assess habitat management as a tool for predator management, but mentioned it as part of broader conservation efforts, or those with a focus on prey habitat enhancement, such as creating scrapes or maintaining sward heights for waders.
2. **Targeted habitat management** (n=28) – Studies that specifically examined habitat modifications designed to reduce predation, deter predators, or evaluate the impact of habitat management methods on natural predation.

There was also some overlap between these two categories, with seven studies incorporating elements of both general habitat management and targeted habitat management.

Target species of non-lethal methods

Foxes were present in 84% of predator exclusion studies, followed by corvids (66%) and mustelids (66%). Invasive species were less frequently cited in these studies (22%), likely due to lethal control being the most suitable method of control for invasive or non-native species. While raptors appeared in 16% of exclusion studies, they were not the intended target of this method.

In contrast, raptors were the primary focus in 65% of diversionary feeding studies, with foxes also cited in 65%. This may be driven by the protected status of raptors in the UK, making non-lethal methods such as this the only legal means of reducing raptor predation on vulnerable prey species. However, in seven of the eleven studies citing foxes, raptors were the primary target, therefore foxes were co-occurring rather than the main focus of this method and were often the target of a different method applied within the same study. Corvids (47%) and mustelids (41%) were also present in some diversionary feeding studies, but in approximately half of these, raptors were the primary target. Invasive species appeared in only 2 studies on diversionary feeding and were not the focus of this method. This is expected as invasive species are more often managed though lethal control aimed at population reduction or eradication.

Conservation implications and public acceptance

The majority of non-lethal studies focused on protecting ground nesting birds, particularly waders (49%) and gamebirds (30%). Predator exclusion was especially relevant for waders, with them being the focus of 78% of exclusion studies.

Non-lethal methods are valuable management tools to consider for land managers, especially in contexts where lethal control is restricted, controversial, or practically inconvenient. Diversionary feeding, for example, offers an alternative for managing protected species like raptors. Similarly, exclusion fencing has been widely studied as a way to reduce fox predation on wading birds without relying on lethal control. One study highlighted the positive outcomes of targeted habitat managed to reduced fox predation on waders and how promoting high nesting densities can mobilise predator mobbing defences (Laidlaw, 2013). This is particularly pertinent for land managers working in public landscapes or on behalf of conservation organisations, where lethal control may be met with membership or public opposition. In such cases, the choice of non-lethal methods can be critical for maintaining public trust and meeting conservation goals.

However, if a non-lethal method is not suitable, open dialogue and education is critical to gaining wider public acceptance of the necessity for such measures. Some social science studies assess public acceptance of different control measures in relation to different species, finding that public acceptance of lethal control is higher for invasive species, and higher again among those who are well-informed on the reasons behind management practices and their efficacy (Bremner & Park, 2007; Caravaggi et al., 2017; Cowley et al., 2018; Dunn et al., 2021).

3.3.3 Duration of Studies

A total of 216 studies explicitly stated their duration, with five of these also incorporating historical data. For 44 studies a timeframe was not applicable, such as literature reviews, while 32 studies relied entirely on historical datasets. A further 25 studies contained multiple varying time frames, though not all durations were specified, and 42 studies did not report their durations at all.

The duration of studies ranged from less than 1 year to 70 years, with modelling studies projected outcomes from 30 to 150 years (n=8). Short-term studies were the most common, with 42 lasting

less than one year and 72 studies spanning 1-4 years (n=72). Mid-long-term studies were also well represented, with 39 studies lasting 5-9 years and 31 studies for 10-19 years. However, studies extending 20-29 years (n=16) and 31-39 years (n=4) were much less frequent, as were extensively long-term studies of 40-70 years (n=4).

This distribution of study durations is likely influenced by the significant time and resources required for longer-term research. While short-term studies are the most common, their value is most often recognised in evaluating the immediate outcomes of predator control methods. Such studies can be particularly informative in assessing the operational feasibility and efficacy of a method as well as short-term behavioural responses of both predator and prey populations. However, long-term studies are essential for capturing any delayed or cumulative effects, such as changes in predator-prey dynamics, habitat use, and the trajectories of targeted species' recovery. The limited number of long-duration studies highlights a potential evidence gap in understanding long-term outcomes arising from management interventions, which is particularly important when informing policy and conservation strategy aimed at long-term nature recovery. Caution is therefore needed when drawing conclusions from or interpreting short-term studies alone, as they may not reflect the broader ecological impacts of the intervention(s) studied. A balanced evidence base, incorporating short- and long-term research across different species and landscapes, is key to capturing complex ecological changes and informing effective, adaptive management strategies that support nature recovery.

3.3.4 Study Limitations

Limitations identified by the authors of the studies were summarised throughout the review process. Some studies did not explicitly outline their limitations, so only those with clearly stated limitations or where limitations were evident during the data extraction phase are included (n=346). This may impact the accuracy of the results presented below. Given the diverse limitations across the studies, four broad categories were identified (Table 4).

Study design limitations were identified in 234 studies, while data limitations were noted in 147 studies and methodological limitations in 131 studies. External limitations were less frequently mentioned, appearing only in 40 studies.

Table 4. Categories of study limitations with descriptions of what may be included in each.

Limitation type	**Description**
Study design limitations	Includes reliance on correlational data (observational bias), small sample sizes, lack of replication, short study duration, limited geographic scope, and theoretical modelling assumptions.
Data limitations	Covers small sample sizes, limited species generalisability, incomplete or inconsistent datasets, observer bias, and lack of baseline data.

Methodological limitations	Encompasses uncontrolled ecological variables, ethical and legal constraints (e.g. species protections limiting empirical comparisons), detection challenges (e.g. cryptic species, reliance on indirect evidence), and biases in survey or trapping methods and species-specific trap responses.
External factors	Includes climate variability, human land management practices, and environmental changes such as habitat loss and disturbances.

Given that most of these studies are field-based and focus on wild populations, many cited variables remain inherently difficult or impossible to control. This limits the strength of causal inferences that can be drawn from individual studies. However, repeated investigations of similar predator-prey interactions across varying spatial and temporal contexts, and within different ecological settings, can build a more robust understanding of potential cause-and-effect relationships. While fully controlled experimental approaches are often unfeasible in ecological fieldwork, synthesising evidence from several peer-reviewed and high-quality grey literature studies allows for a more nuanced interpretation. In doing so, the collective weight of the literature can help mitigate the influence of individual study limitations on broader conclusions about predation and predator control.

3.4 Impacts and Outcomes

3.4.1 Impacts on Predators

Effects of an intervention on predator species were mentioned in 271 studies, whilst 21 did not discuss this and for 66 studies this was not applicable due to the focus of the study being on the impacts on the prey species. Ultimately, the purpose of most studies was to measure the effects of predation and varying types and levels of control rather just to reduce the predator population.

Of the 206 studies that focused on lethal predator control (some alongside other methods, or comparators) 191 mentioned the effects of control on the predator species studied. However, many studies only commented on the reduction of the predator population, with some giving specific numerical values and others more broadly discussing compensatory increases in other predator populations. All studies that focused on lethal control did at least discuss the efficacy of the control method used (e.g. effective in reducing predator population, effective/not effective in improving prey species breeding success/reducing predation pressure, requires more testing in differing population densities).

As short-term studies dominated the dataset, it would not be possible in most cases to draw broader implications for predator species at a local population level as the study periods (i.e. 1-2 years) were often shorter than the predators' lifespans and therefore too brief to capture the effects of control on subsequent generations. Although, some mid-to-long-term studies (5-19 years) did note local recolonisation of species such as foxes, suggesting that sustained control

may be necessary to maintain a reduced predator population, in the absence of natural predation and for the time necessary for the prey species to recover. On the other hand, some studies reported perceived compensatory increases in other mesopredator species. For example, badger culling was associated with local increases in foxes and hedgehogs, potentially shifting the balance of predator pressure (Kettel et al., 2021) and in another case, generalist predators appeared to compensate for reduced weasel populations (KorpimÃ¤ki et al., 2005). One study noted other mammalian and avian predators moving into areas where weasels had been successfully reduced (KorpimÃ¤kiet al., 2003), and in one upland site, reductions in crows and gulls were offset by increased fox activity, which prevented a noticeable recovery in golden plover numbers (Parr, 1993). This suggests that unintended ecological trade-offs are occurring, raising the question of whether or to what extent lethal control may in some cases shift predation pressure rather than reducing it, and what this means for the prey species aimed to benefit from predator control. However, these compensatory species were often generalist predators such as foxes and corvids - which are themselves legally controllable – emphasising both their adaptability and the challenge of achieving sustained ecological outcomes through single-species control strategies. These patterns underscore the need for longitudinal studies that not only assess immediate efficacy of control methods and potentially instant benefits to prey species of conservation concern, but also their long-term impacts on species dynamics.

3.4.2 Impacts on Prey

For each study in the database, the overall outcome of control was assessed based on the studies' information on the methods' efficacy and impacts on the prey species. These were categorised broadly as positive, neutral, negative, and mixed. For some studies the outcomes were unclear or not applicable, for example where this was not a primary focus of the study.

Both lethal and non-lethal control methods had mostly positive outcomes on prey species with less than 5% having overall negative outcomes, although a small proportion did report mixed impacts (Table 5). Of the studies on reintroduction or biological control, 79% had or expected positive outcomes and 15% had mixed outcomes (note, most of these were predictive or modelled studies).

Studies in the 'no control' category are divided into two further categories in this section: those where 'no control' was the primary approach, and those where it served as a comparator to lethal or non-lethal control methods. The sample size of studies comparing no control with non-lethal control (n=9) was too small to give meaningful results. In studies comparing lethal control to no control, no control scenarios resulted in no broad positive outcomes but did result in negative outcomes 62% of the time, with neutral and mixed results making up 14% collectively. Contrastingly, no control scenarios that had no comparison to any control strategy demonstrated positive outcomes in 16% of cases, and negative outcomes in 44% of cases, with 17% of studies having neutral results.

Table 5. The percentage of positive, negative, neutral, and mixed outcomes in relation to each control category.

Control category	Category (n)	Positive (%)	Negative (%)	Neutral (%)	Mixed (%)	Unclear (%)	N/A (%)
Lethal	225	62	4	9	17	3	5
Non-lethal	119	52	2	6	8	3	29
Reintroductions	34	79	0	0	15	0	6
No control (no comparator)	63	16	44	17	5	6	11
No control (in comparison to lethal control)	29	3	62	7	7	21	0

Of the 130 studies demonstrating positive outcomes of lethal predator control, just less than half (42%) were studies on waders as the prey species. For non-lethal control studies and studies involving no control with positive outcomes, waders were a focus of a third of them (31% and 33%, respectively). Interestingly, 42% of studies involving no predator control that had negative outcomes, were also focused on waders, with 23% each relating to songbirds and small mammals. This result highlights the importance of identifying the most effective management strategies to protect the many species within these groups that are important to UK nature recovery goals.

These results of the studies indicate that both lethal and non-lethal predator management methods generally have positive outcomes for prey species, with only a small proportion showing negative or mixed impacts. Studies on reintroduction or biological control methods also yielded predominantly positive results, though it's important to recognise that these studies were primarily modelling or theoretical in nature, with limited field-based evidence relevant to the UK context. As such, caution should be taken when interpreting these results, as real-world outcomes may differ.

On the other hand, studies with no control revealed mixed results; those comparing no control with lethal methods saw negative outcomes 62% of the time, highlighting the risks of inaction. Waders were particularly impacted, with nearly half of the negative outcomes from 'no control' studies affecting this group. These findings underscore the importance of tailored predator management strategies for species recovery, particularly key species like waders and small mammals, which are critical to UK nature recovery goals, such as the importance of mink eradication for water vole recovery (Harrington et al., 2020).

Furthermore, several studies highlight the complimentary role of habitat management alongside predator control to enhance prey survival. For example, capercaillie conservation efforts in Scotland illustrate how predator control must be delivered in parallel with native woodland

restoration and small mammal recovery, which together provide suitable nesting habitat and alternative prey for predators, ultimately reducing predation pressure on capercaillie chicks (NatureScot, 2015; Kämmerle & Storch, 2019; Baines et al., 2004). In one of the public perception studies reviewed in this QSR, this integrated approach was perceived to be highly effective (Philip and Macmillan, 2003). Similarly, sustained population increases in wader were achieved where predator control was paired with targeted habitat interventions (Ludwig et al, 2019), while grouse recovery required periodic management combined with ongoing habitat management (Park et al., 2002). Other studies also reinforced that predator control alone may be insufficient without complementary measures (Warren & Baines, 2002). Collectively, these findings emphasise the importance of integrated strategies that consider both immediate underlying ecological factors influencing species survival in the long-term.

The role of some mustelids (e.g. badgers) and raptors that are protected species can compensate for the reduction of other predators, potentially increasing their populations which can still have a knock-on effect on other important protected prey species (Roemer et al., 2009; Hetherington, 2006). This highlights the need for holistic approaches in conservation efforts relevant to the predator and prey species, integrating both predator control, non-lethal methods, and habitat management strategies to support long-term species recovery. It's important to recognise that not everything can recover all at once; balance is needed to ensure sustainable recovery across ecosystems. Together these integrated strategies can all play a key role in supporting the UK's nature recovery goals.

3.5 Knowledge Gaps and Future Research

Although the evidence base dates back to 1970, research has progressed considerably since then. Many evidence gaps identified in older studies have likely been addressed in more recent publications, making them less relevant to current priorities for future research. To ensure temporal relevance and focus on findings with implications that remain pertinent today, this section considers only studies published from 2010 onwards (n=209).

3.5.1 Knowledge gaps

The knowledge gaps identified by study authors varied in detail but were mostly related to ecological and biological uncertainties. The gaps often overlapped with the limitations discussed in studies (section 3.3.4) and have been similarly categorised into four broad groups:

1. **Ecological and biological uncertainties** - including limited understanding of short- and long-term impacts, unintended effects on other species, compensatory predation, trophic cascades, behavioural adaptations of predators or prey, and the scale of impact (local vs landscape).
2. **Environmental and contextual factors** - encompassing variation across ecosystems, species, and seasons, or the effects of environmental change (e.g. climate change) on predatory-prey dynamics.

3. **Ethical and social considerations -** such as stakeholder communication, public perceptions and welfare concerns.
4. **Methodological and data limitations** - typically related to sample size or study duration.

Ecological or biological uncertainties were the most frequently cited knowledge gap, mentioned in 90% of studies. Interestingly, around half of the studies for each of the key predator and prey groups cite this as a knowledge gap, with the exception of foxes, where only 5% of studies highlighted such uncertainties. This suggests that foxes are comparatively well understood in the UK, likely due to their widespread presence in both rural and urban settings and frequent interactions with human environments, which has prompted research into their ecology and behaviour.

Environmental and contextual factors were reported across all key species groups (34% of studies), reinforcing the importance of continued research under changing environmental conditions. The ongoing influences of climate change, land use variability, and species' seasonal dynamics emphasises the need for flexible, adaptive research frameworks that reflect real-world complexities.

Fewer studies cited methodological/data limitations (8%) and ethical and societal considerations (4%) as knowledge gaps. However, this low frequency may not reflect a lack of importance but rather a tendency for these issues to be underexplored or overlooked within the scope of ecological studies. For example, social acceptance of predator control methods, or ethical implications of management strategies, may not be prioritised or considered and therefore are left underexplored. A greater emphasis on these perspectives could enrich our understanding and improve the design of predator control practices.

3.5.2 Further Research

Most further research recommendations made by study authors focused on the effectiveness and trade-offs of predator control and alternative or holistic management approaches. Four key research categories were identified and are detailed below:

1. **Effectiveness and trade-offs of predator control** - includes calls for direct comparative analyses between control methods, before-after comparisons, cost-benefit analyses, and assessments of broader ecosystem impacts (e.g. effects on nature recovery).
2. **Alternative or holistic management approaches** – identifies the need to investigate the efficacy of habitat-based solutions, rewilding/restoration strategies, and adaptive management techniques.
3. **Social and human dimensions of predator control** – suggests a need for community understanding, acceptance, and involvement, as well as strategies for mitigating human-wildlife conflicts.

4. **Innovation and emerging methods in the 'management tool box'** - primarily technology driven solutions such as use of drones, new tracking/monitoring methods for cryptic species, and development of new non-lethal deterrents.

Three quarters (n=157) of the further research recommendations are related to the effectiveness and trade-offs of predator control, while 50% fall under alternative or holistic management approaches. Recommendations concerning social and human dimension or innovation in predator management or monitoring approaches were less common, each accounting for 8% of suggested research avenues.

The representation of key species groups in recommendations related to effectiveness of predator control and alternative management approaches are generally proportional of their occurrence in the database (Appendix: Table 1). However, wader studies, which make 36% of the database, were notably overrepresented in research calling for alternative predator control approaches (47%) and innovative methods (65%). Although the latter is based on a small sample size (n=17), it is interesting to note that fox studies contributed the same number of studies (n=11) to the innovative methods category as wader studies, with a significant overlap (n=9) between the two. This suggests that the high representation of waders in this category may be driven by the need for research on foxes as a primary predator, rather than on wader monitoring alone. Additionally, the overrepresentation of waders may also reflect the impact of other predators, such as badgers, hedgehogs, pine marten, and ravens, all of which are protected. Given that their protected status and potential to fill the ecological gaps of other predators that can be lethally controlled, the populations of these species could increase (as is intended by their protection), leading to increased predation occurrence. Consequently, innovative research into exclusion and deterrence methods is needed, particularly in the face of limited licencing for lethal control or relocation.

Given that waders are a high priority group for nature recovery in the UK, it is crucial to prioritise predator control research that benefits these species. Nest predation, affecting both adults on nests and eggs or chicks, is one of the greatest challenges facing waders (BTO, 2025; Ewing et al., 2022; Silva-Monteiro et al., 2023). Monitoring and protecting wader nests is particularly difficult due to several factors. For example, monitoring devices, which could help track nests, may attract predators or cause nest abandonment. Tracking adult waders with mobile chicks is also problematic as nest sites are no longer static. Where wader populations are substantial, acquiring sufficient monitoring equipment to cover all nests or predict which ones are most at risk of predation becomes a challenge, with the latter option introducing sampling bias. These difficulties are compounded in species with cryptic behaviour, such as curlew (Ewing et al., 2023), which make accurate monitoring even more challenging. With curlew populations experiencing steep declines over the last three decades and now listed as Near Threatened on the IUCN Red List (BirdLife International, 2021), there is a pressing need to develop improved monitoring methods alongside predator control strategies to support their recovery (Brown et al., 2015; Baines et al., 2023).

To address these challenges, research should shift its focus from merely asking if predation is occurring and its population-level impacts, to how predation events are occurring, who the predators are, and what deterrent or control methods are most effective. These behavioural

focused studies, however, are far more difficult to design and execute at a scale that allows for extrapolation to broader population levels or landscape scales.

4. Conclusion

This review highlights the complex and often context-dependent nature of predator control as a conservation tool in the UK. Drawing on a wide body of evidence, spanning several decades, it is clear thar both lethal and non-lethal predator management methods can yield positive outcome for prey species, especially when aligned with specific conservation objectives and in conjunction with habitat management. However, outcomes are variable and influenced by ecological, environmental, and methodological factors - there is no one-size fits all solution to nature recovery.

Lethal control is the most studied approach, especially in relation to legally controllable generalist predators such as foxes and has proven effective in reducing local predator populations and improving nesting success or reducing predation of prey species. However, these studies are typically short-term and frequently fail to capture longer-term dynamics such as predator recolonisation or compensatory responses by other predators. This reinforces the need for sustained monitoring efforts and long-term research, particularly for predators relevant to species of high conservation concern like wades and small mammals. Effective conservation requires a balanced approach with trade-offs and prioritisation to avoid unintended consequences, including the risks of inaction. While precaution is important, doing nothing can sometimes result in worse outcomes for vulnerable species and ecosystems.

The implementation of lethal control also requires a specialised skillset including proficiency in safe and legal trap placement, marksmanship when shooting, licensed firearm use, and a practical understanding of the target species' behaviour. Much of this knowledge and capability currently exists within the UK shooting community, where it is supported by established training programmes and best-practice guidance. These skills, alongside access to land, make the shooting sector an indispensable part of predator management in many rural areas. Importantly, the role of this sector is not limited to predator control alone, but extend to monitoring, record-keeping, and habitat stewardship, all key aspects of integrated conservation strategies.

Non-lethal methods, such as exclusion, deterrents, and translocation offer promising avenues for complementary or alternative approaches. These methods are often the focus of current research and innovation and may open up predator management to a broader range of stakeholders beyond landowners and the shooting community and could play a valuable role in increasing public acceptance of predator control as part of broader conservation efforts. This is particularly important for many conservation organisations whose members/supporters do not support lethal control methods. However, these methods are not without limitations and are often most effective when used alongside traditional lethal control methods. Therefore, predator management should not be viewed as a binary choice between lethal and non-lethal, but rather a toolbox of

interventions, with the most suitable combination of tools chosen according to specific contexts and conservation goals.

Despite the progress made over several decades of research, some major knowledge gaps still persist, particularly concerning the long-term ecological effects of predator control, behavioural responses of predators and prey, and broader trophic interactions. While ecological uncertainties dominate, underexplored areas such as public perceptions and social acceptability of the available tools also warrant greater attention. These perspectives are crucial to fostering wider support for sustainable predator management practices, ensuring that current and future strategies are scientifically sound. It is vital that stakeholders, conservation organisations, and the public alike recognise that predator management – whether lethal or non-lethal – is an essential tool in conservation, directly contributing to the recovery of vulnerable species and ecological balance in the absence of apex predators.

Looking forward, considerations for future research include:

- Comparative evaluations of different control methods, including cost-effectiveness and long-term ecological impacts and outcomes.
- Expanded investigation into non-lethal options, which could help engage a wider community and support in predator control and nature recovery efforts.
- Integration of habitat management and adaptive strategies that reflect real-world conservation challenges.
- Increased efforts towards social science research to guide communication and engagement between practitioners, the public, policy makers, and stakeholders.

In conclusion, predator control, when implemented with care, collaboration, and clear conservation goals, can make a substantial contribution to the UK's nature recovery goals. Achieving this will require a balanced, integrated approach, recognising the roles of both traditional land managers and emerging innovations and combining long-standing expertise with forward-thinking research.

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Appendix 1

Database column headings

- Evidence ID
- Author
- Title
- Abstract/summary
- Year of publication
- Source (Google Scholar or Web of Science)
- Publication type (e.g. journal article, conference proceedings, PhD Thesis)
- Full citation
- Country
- County/region
- Ecosystem/habitat type
- Predator species
- Prey species
- Study aims
- Lethal, non-lethal, no control, biological control
- Type of predator management / conservation intervention
- Other types of management/intervention mentioned
- Study type (e.g. observational, experimental, literature review)
- Study design (e.g. use of camera traps, field work)
- Sample size
- Duration
- Main outcomes
- Impact of intervention on predator population(s)
- Impact of intervention on prey population(s)
- Impact of intervention on ecosystem
- Nature recovery outcomes
- Overall positive, negative, neutral outcome from no/alternative intervention
- Overall positive, negative, neutral outcome from predator control/management
- Efficacy of control method
- Main findings
- Study limitations
- Knowledge gaps
- Suggestions for further research
- Level of relevancy to QSR
- Author affiliations
- Funding source

Table 1. The number of studies on each prey species group for each key predator group.

Prey species groups	Number of fox studies	Number of corvid studies	Number of mustelid studies	Number of raptor studies	Number of invasive predator studies	Number of gull studies
Waders	92	86	47	30	21	14
Terns	6	3	1	2	11	9
Songbirds/farmland birds	35	49	19	28	17	4
Small mammals	42	14	49	29	42	1
Seabirds	2	1	1	0	7	9
Raptors	7	8	5	2	4	0
Other/unspecified	6	3	4	4	6	0
Non-quarry gamebirds	7	6	7	5	3	0
Mid-large mammals	6	0	3	3	1	0
Invertebrates	6	4	4	3	3	0
Gulls & Kiitiwakes	6	1	2	0	5	4
Gamebirds (quarry species)	80	61	32	50	14	3
Extinct/considered for reintroduction	0	0	1	1	0	0
Doves & Pigeons	5	3	5	7	5	0
Cranes, Storks, and Waterbirds	2	1	2	2	3	0
Corvids	2	2	3	5	2	0
Bats	0	1	0	1	0	1
Anseriformes	3	0	3	1	5	2
Amphibians & reptiles	1	1	0	1	1	0

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