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Is there a wild animal welfare emergency facilitated by negative linguistic framing in wildlife population control studies?†

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Abstract: As the world human population continues grow in number and mobility, and the impacts of climate change take effect, the opportunities for problematic relationships with non-human animals multiply. There are escalating threats to health from wild vectors of zoonotic disease, and so called 'invasive' species have been identified as a significant direct driver of an unprecedented period of global biodiversity loss. This brings a sense of genuine urgency to control problematic wild populations; in the UK alone, it is estimated that 38 million wild mammals and birds are killed as pests. However, the impact of these animals is not always objectively appraised. Control interventions are often ineffective, may be counterproductive and can cause severe suffering. Decisions about when, where and how to control animal populations can be affected by attitudes and philosophical perspectives, influenced by how language is used.

A systematic review of wildlife population control studies was carried out to determine whether negative linguistic framing of animals was associated with poor welfare outcomes. Framework analysis of titles, abstracts and keywords was used, and assessments made of the welfare impacts of control methods. This analysis revealed language that framed target populations in terms of War, Threat, Place, Victim, Value, Sentience and Naturalness with a range of associated themes. There was a relationship between negative framing and methods with the most adverse welfare outcomes, but the effect was not consistent. It was clear that there are cultural conventions within the science that were reinforced or challenged depending on many factors including the status of the species and the context of the intervention. More work to explore and challenge cultural conventions in describing targeted animals, and robust reporting of the welfare impacts of control methods are needed to tackle this, often disregarded, animal welfare emergency.

Keywords: Wildlife population control; Wild animal welfare; Welfare assessment; Linguistic framing; Invasive species; Pest management; Systematic literature review

1. Introduction

Associations between humans and wild non-human animals (hereafter animals) have been problematic since pre-history [1].The global human population (projected to rise to 11 billion people by 2100 [2]) are increasingly mobile, this multiplies opportunities for problematic interactions. Humans encroach on wild areas and introduce species to novel habitats, and climate change alters the range of some species [3]. The IPBES have identified 'invasive' species as a direct driver of biodiversity loss [4].

Animal suffering

Approximately 38 million wild mammals and birds are shot, snared, trapped or poisoned in the UK each year [5]. Some interventions cause severe suffering but the regulation of methods of control is less cognisant of welfare than for animals in other contexts. Methods that would otherwise require sedation or analgesics are routinely used in the control of wild populations and time to insensibility of up to 300 seconds is considered acceptable [6].Additionally, the Small ground vermin traps order 1956 exempts spring traps for rats, mice and moles from quality regulation.

Attitudes to animals

Human cultures have to manage contradictions in how animals are treated [7]. There are different rules governing the treatment of animals as family (pets) and animals that are a nuisance (pests). Cognitive dissonance has been proposed as a phenomenon that enables the justification of behaviour that doesn't attune with a person's values [8], and it has been proposed that language and labelling influences attitudes to wild animal species [9].

Linguistic framing

Linguistic framing uses language to conceptualise a subject as a defined problem, with a particular cause and solution[10]. It works by highlighting aspects of the subject which accentuate its salience and projects a moral judgement [10]. It de-emphasises characteristics that would contradict the intended paradigm [10]. Framing may be used intentionally as a tool of persuasion or may unconsciously, reflect cultural bias [11]. Cultural context affects the way a framed concept is received, the effect may be different depending on the receiver's, previous experiences [12]. An 'ends justify the means' philosophy can be more palatable when a target species is presented as a sufficient threat to a protected species or environment that is framed as precious and vulnerable [13]. How animals are framed differently according to context is apparent in grey literature [14] but is also in scientific writing [15]. As titles, abstracts and keywords distil the content of papers and have the furthest reach [16], so analysis of them could provide insight into whether negative framing is associated with animal suffering.

Systematic reviews have been used to for qualitative research [17], to investigate the influence of metaphor on attitudes [18] and can reveal how discourse frames issues to emphasise a perspective [19].

2. Materials and Methods

After a systematic search had been carried out (S1 and S2) and all relevant texts identified and obtained. Abstracts of papers were searched for linguistic themes and descriptive and in vivo codes were recorded [20]. Welfare was rated using Sharp and Saunders' (2011) model which assigns two scores: (A) rates the overall suffering, by plotting duration against intensity (scores 0-8), and (B) rates the mode of death in terms of time to unconsciousness and level of suffering (A-G).[21].

Discourse analysis using a framework analysis approach was used, this allowed the use *of a priori* themes but also allowed for an iterative element so new themes that emerged from the texts would not be overlooked [22]. Detailed analysis of titles abstracts and keywords was carried out using the qualitative data analysis software Atlas.ti [14]. Themes were assigned to framing categories as code groups. Documents were organised by method, and the query tool was used to interrogate the frames and themes for each. A "Full content" report was generated for each frame within each document group; this identified quotations, comments and themes. These themes were examined and identified quotations that represented the prevailing attitudes and positive, negative or neutral tone of the relevant papers. Relationships between method of control, welfare and frames and themes could then be inferred.

Mupepele et al., (2014)'s quality assessment format (designed for conservation studies) was adapted and used to assess the included papers. This method grades the Level of Evidence (LoE) on a hierarchy from weak to strong. (S3).

3. Results

The literature search retrieved the following numbers of records: Web of Science: 1843 records; EBSCO 430 records; Open Grey: 75 records; DEFRA 385 records; NI Assembly: 70 records. After duplicates were removed and titles, abstracts and finally full text papers were screened, the abstracts of 65 papers were available for analysis. Texts spanned 45 years from 1974 to 2019. The *a priori* frames were confirmed in the literature: **War**, **Place**, **Victim**, **Value**, **Sentience**, **Threat** and **Natural** with an additional **Sentience** frame which proved integral to setting the tone in many of the studies.

Poison

The use of poison resulted in poor welfare outcome and framing was overwhelmingly negative. Animals. The theme of "infestation" was amplified by repetition and emphasis on size and seriousness; infestations were "heavy" and "substantial" and populations were "abnormally large". "Rodenticide" "resistance" activated **War** as an image. **Sentience** was used for sabotage Rats "rejected bait" and removed burrow blocking materials but also depicted rats' sociability and cognitive sophistication. Additionally, **Place** themes of colonisation were neutralized by themes of "living in", being "resident", or being "occupants". and domestic images of "home.: Mice were objectified, their rebounding populations were simply a "build-up".

Live trap and despatch (LTD) and kill traps

Welfare outcomes were mixed, dependent on trap inspection regime, handling and trap quality Corvids, caught in Larsen or Ladder traps, likely suffered the most harms. Framing was negative or neutral, with differences between species (corvids neutral, mink negative others mixed). **War** themes framed traps that were "deployed" and "armed", and intervention as a "campaign", particularly in studies that involved the public in killing. **Threat** and **Place** was intensified through repetition, "alien invasive" and "harmful invasive" and "abundance". Pathogenic and competitive grey squirrels were juxtaposed with their native red victims **Threat** to native reds. **War** and **Threat** was also emphasised by the means of control, for example "Magnum 116 bodygrip traps" evoked weaponry.

Exclusion

Welfare was generally good in exclusion interventions. Tone was mixed with examples of positive, neutral and negative framing all represented. **War** themes ("recruitment", "target"), and **Threat** ("crop damage") were offset by **Value** themes ("individuality", "social animals", "welfare"). **Sentience**, revealed "social", "cognitively complex" with "individuals" with the agency to make decisions and as having preferences. **Place** was either neutral ("home ranges") or negative ("Immigrant").. In contrast there were powerful images of conflict; badgers made "incursions" into forbidden areas and rabbits were "recruited"., exclusion fencing was often "deployed". Negative framing was more apparent there were more severe welfare impacts.

Repellents

Welfare was generally good. The tone of the papers was neutral, and all frames were represented; **Value** and **Sentience** dominated, with numerous themes relating to the animals' subjective experience, of "sensing", "cognitive complexity" and "agency". **Sensing** was depicted in their discrimination between treated and untreated conditions. Animals were presented as legally protected (**Value**) and public opinion was important in the choice of "benign" control. Badgers were **Natural** but also a **Threat**, contextualised as pests that have negative impacts though economic costs and crop damage.

Other methods

Other methods showed a similarly loose association between the tone of framing and welfare outcomes (Table 1).

Table 1 The relationship between the tone (positive, negative or neutral) and welfare outcomes for wildlife population control studies, showing number of studies (n), study quality and years of publication

Method (n)	Negative	Positve	Neutral	Welfare	Quality	Years
Poison (14)	✓			Poor	Low	1978-2007
LTD/kill traps (15)	✓		✓	Mixed	Mixed	2000-2017
Exclusion (9)	✓	✓	✓	Good	Good	2000-2009
Repellents (7)			✓	Good	Good	2002-2006
Deterrents (5)	✓	✓	✓	Good	Good	2001-2019
Shooting (4)	✓	✓	✓	Mixed	Mixed	1974-2018
Fumigation (2)			✓	Poor	Low	1986-2002
Habitat modification (5)	✓	✓		Good	Mixed	1987-2008
Translocation (1)	✓			Mixed	Good	1996
Immunocontraception (1)	✓			Mixed	Good	2011

Discussion

Seven framings: **War**, **Place**, **Victim**, **Value**, **Sentience**, **Threat** and **Natural**. Those previously reported [14,24,25], but the additional **Sentience** frame proved integral to setting the tone in many of the studies. Poison studies showed negative framing and had poor welfare outcomes. Most of these studies targeted rats. This may reflect the long-held associations between rats and negative human characteristics, they are commonly objects of phobias and disgust [26], and are used as a metaphor to stigmatise other species, pigeons are denounced as "rats with wings" [27], squirrels as "tree rats" [28]. Mixed framing and variation in outcome was found where LTD and kill traps were used. The War on wildlife was epitomized in mink studies which were the majority in this group and were exclusively negatively framed. There was a striking intensity that integrated **War**, **Threat** and **Place**. The "alien", "invasive", "harmful", "diseased" mink and squirrels were juxtaposed with "native" victims. that projects were attempting to re-establish. This was evident in studies that involved members of the public in carrying out lethal control [29]. The necessity for exaggeration of **Threat** is could be because the public tend not to favour lethal control even where it is presented as more effective and less costly than other means [30]. Moreover, the public are more likely to approve of lethal interventions when a problem species has been deliberately or negligently introduced by humans, so this communication technique could both encourage public participation and dampen opposition [31]. In contrast, corvids were framed neutrally but control methods had poor welfare outcomes, these birds are traditionally disliked in the UK [32], so there may be less need to justify the welfare harms. Additionally, the control actions for corvids were directed by the authors but carried out by professional gamekeepers for whom the interventions would have been routine.

The inconsistent relationship between framing and welfare may reflect cultural conventions in how animals are perceived. Some species evoke contradictory feelings, for example badgers are native animals but generate extreme oppositional opinions [14]. Additionally, few wildlife population control operations report the actual welfare impact in their studies and much of the literature regarding welfare is based on older studies some only based on self-reported effects in humans [33].

Conclusions

There was a relationship between negative framing and poor welfare, but this was complex, particularly as there were cultural influences on how species were represented. Negative framing was most apparent in the poison and LTD and kill traps method group, but even within groups there was variation in tone and emphasis. The loosest connection between framing and welfare was in the

management of corvids, which were neutrally framed but subject to high welfare risks. In these studies authors were detached from the intervention by employing the gamekeepers to carry out the control. The analysis has shown that framing is a complex phenomenon and mere policing of language would likely have little influence on how animals are perceived or improve welfare outcomes. The analysis was hindered by a lack of robust reporting of animal welfare in wildlife population control research, potentially obscuring a large-scale welfare emergency. This could be improved if auditing and reporting of welfare impacts could be implemented in future.

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Supplementary Information 1

Search strings

. Web of Science

- Advanced search
- All databases
- All years
- English language
- Refine – check 'article' only

- 1,842 results on 07/07/19

("spring trap" OR "spring traps" OR "live trap" OR "live traps" OR "glue trap" OR "glue traps" OR "sticky trap" OR "sticky traps" OR "scissor trap" OR "claw trap" OR "duffus trap" OR "talpa trap" OR "mole trap" OR translocation OR translocations OR cull OR culling OR shoot OR shooting OR hunt OR hunting OR stalking OR immunocontraception OR "contraceptive vaccine" OR poison OR poisons OR poisoning OR rodenticide OR rodenticides OR "anticoagulant rodenticides" OR "first generation anticoagulant rodenticides" OR FGAR OR FGARS OR "second generation anticoagulant rodenticides" SGAR OR SGARs OR bromadiolone OR cis-bromadiolone OR brodifacoum OR difethialone OR chlorophacinone OR diphacinone OR flocoumafen OR warfarin OR coumatetralyl OR norbormide OR fumigant OR fumigants OR "alpha-chloralose" OR "alpha chloralose" OR alphachloralose OR "hydrogen cyanide" OR phosphine OR "phosphine gas" OR strychnine OR "larsen trap" OR "larsen traps" OR "ladder trap" OR "ladder traps" OR "gin trap" OR "gin traps" OR "leg hold trap" OR "leg hold traps" OR "tunnel trap" OR "tunnel traps" OR "tunnel trapping" OR "trap barrier system" OR "trap barrier systems" OR "trojan female technique" OR "sterile male technique" OR "cranial dispatch" OR "cervical dislocation" OR removal OR "population removal" OR "population removals" OR eradication OR "rodent proofing" OR "pest proofing" OR falconry OR ferreting OR "conditioned taste aversion" OR "habitat modification" OR "habitat management" OR "scaring device" OR "olfactory inhibitors" OR "olfactory inhibitor" OR "electric fence" OR "leg cuff")

AND

("human wildlife conflict" OR "population control" OR "predator control" OR "predation impact" OR "predator impact" OR "nest predation" OR "wildlife management" OR conservation OR biosecurity OR "bovine tuberculosis" OR btb OR "environmental health" OR "crop damage" OR "crop protection" OR "protecting native species" OR "native species protection" OR "economic impact" OR "economic impacts"-OR "food hygiene" OR "disease prevention" OR "pest invasion" OR invasion OR reinvasion OR "alien invasion" OR vermin OR alien OR "target species" OR "alien species" vermin OR pest OR "invasive pests" OR "invasive pest" OR invasives)

AND

("target species" OR rodents OR rat OR rats OR "black rat" OR "ship rat" OR "ship rats" OR "rattus rattus" OR r.rattus OR "norway rat" OR "norway rats" OR "brown rat" OR "brown rats" OR "rattus norvegicus" OR r.norvegicus OR mouse OR mice OR murid* OR muroid*" OR "mus musculus" m.musculus OR "golden hamster" OR "golden hamsters" OR syrian hamster" OR "syrian hamsters" OR "mesocricetus auratus" OR m.auratus OR "prairie dog" OR "prairie dogs" OR "black tailed prairie dog" OR "black tailed prairie dogs" OR "cynomys ludovicianus" OR c.ludovicianus OR "edible dormouse" OR "edible dormice" OR "glis glis" OR g.glis OR "american mink" OR "neovison vison" OR n.vison OR muskrat OR muskrats OR "ondatra zibethicus" OR o.zibethicus OR "red deer" OR "cervus elaphus" OR c.elaphus OR "roe deer" OR "capreolus capreolus" OR c.capreolus OR "fallow deer" OR "dama dama" OR d.dama OR "muntjac deer" OR "muntiacus reevesi" OR m.reevesi OR "sika deer" OR "cervus nippon" OR c.nippon OR "Chinese water deer" OR "Hydropotes inermis" OR h.inermis OR "european rabbit" OR "european rabbits" OR rabbit OR rabbits OR "oryctolagus cuniculus" OR o.cuniculus OR mole OR moles OR "european mole" OR "european moles" OR "talpa europaea" OR t.europaea OR badger OR badgers OR "european badger" OR "european badgers" OR "meles meles" OR m.meles OR hedgehog OR hedgehogs OR "european hedgehog" OR "european hedgehogs" OR "erinaceus europaeus" OR e.europaeus OR stoat OR stoats OR "mustela erminea" OR m.erminea OR coypu OR "myocastor coypus" OR m.coypus OR porcupine OR porcupines OR "himalayan porcupine" OR "himalayan porcupines" OR "hystrix hodgsonii" OR h.hodgsonii OR "hystrix brachyura" OR h.brachyura OR fox OR foxes OR "red fox" OR "red foxes" OR "vulpes Vulpes" OR v.vulpes OR squirrel OR squirrels OR "grey squirrel" OR "grey squirrels" OR "sciurus carolinensis" OR s.carolinesis OR hare OR hares OR "mountain hare" OR "mountain hares" OR "lepus timidus" OR l.timidus OR "brown hare" OR "brown hares" OR "european hare" OR "european hares" OR "lepus europaeus" OR l.europaeus OR weasel OR weasels OR "mustela nivalis" OR m.nivalis OR "wild boar" OR "wild boars" OR "sus scrofa" OR s.scrofa OR "eurasian beaver" OR "eurasian beavers" OR "european beaver" OR "european beavers" OR beaver OR beavers OR "castor fiber" OR c.fiber OR corvid OR crow OR "carrion crow" OR "corvus corone" OR c.corone OR "hooded crow" OR "corvus cornix" OR c.cornix OR jackdaw OR "corvus monedula" OR c.monedula OR jay OR "garrulus glandarius" OR g.glandarius OR magpie OR magpies OR "pica pica" OR p.pica OR raven OR ravens OR "corvus corax" OR c.corax OR rook OR rooks OR "corvus frugilegus" OR c.frugilegus OR pigeon OR pigeons OR "rock dove" OR "columba livia" OR c.livia OR "stock dove" OR "columba oenas" OR c.oenas OR dove OR doves OR "collard dove" OR "collard doves" OR "streptopelia decaocto" OR s.decaocto OR "wood pigeon" OR "wood pigeons" OR woodpigeon OR woodpigeons OR "columba palumbus" OR c.palumbus OR seagull OR seagulls OR "herring gull" OR "herring gulls" OR "larus argentatus" OR l.argentatus OR "lesser black backed gull" OR "lesser black backed gulls" OR "larus fuscus" OR l.fuscus OR "great black backed gull" OR "great black backed gulls"

OR "larus marinus" OR l.marinus OR goose OR geese OR "greylag goose" OR "greylag geese" OR "anser anser" OR a.anser OR "egyptian goose" OR "egyptian geese" OR "alopochen aegyptiaca" OR a.aegyptiaca OR "canada goose" OR "canada geese" OR "branta canadensis" OR b.canadensis OR "ruddy duck" OR "ruddy ducks" OR "oxyura jamaicensis" OR o.jamaicensis OR parakeet OR parakeets OR "monk parakeet" OR "myiopsitta monachus" OR m.monachus OR "ring-necked parakeet" OR "ring-necked parakeets" OR "rose-ringed parakeet" OR "rose-ringed parakeets" OR "ring necked parakeet" OR "ring necked parakeets" OR "rose ringed parakeet" OR "rose ringed parakeets" OR "psittacula krameri" OR p.krameri OR starling OR starlings OR "european starling" OR "european starlings" OR "sturnus vulgaris" OR s.vulgaris OR sparrow OR sparrows OR "house sparrow" OR "house sparrows" OR "passer domesticus" OR p.domesticus OR buzzard OR "Buteo buteo" OR b.buteo OR "hen harrier" OR "hen harriers" OR "Circus cyaneus" OR c.cyaneus OR "grey seal" OR "Halichoerus grypus" OR h.grypus OR "common seal" OR "harbour seal" OR "Phoca vitulina" OR p.vitulina OR "feral cat" OR "felis catus" OR f.catus)

AND

("great Britain" OR GB OR "united kingdom" OR uk OR England OR "North East England" OR "Yorkshire and Humberside" OR "East of England" OR "East Anglia" OR "Eastern England" OR "The West country" OR Merseyside OR Scotland OR wales OR "Northern Ireland" OR Hebrides OR Hebridean OR "outer hebrides" OR Orkneys OR "orkney islands" OR "Shetland Isles" OR Shetland)

EBSCO

- Advanced search
- Check 'Boolean/Phrase'
- Uncheck 'Apply equivalent subjects'
- Select 'English' language

- 429 results on 07/07/19

("spring trap" OR "spring traps" OR "live trap" OR "live traps" OR "glue trap" OR "glue traps" OR "sticky trap" OR "sticky traps" OR "scissor trap" OR "claw trap" OR "duffus trap" OR "talpa trap" OR "mole trap" OR translocation OR translocations OR cull OR culling OR shoot OR shooting OR hunt OR hunting OR stalking OR immunocontraception OR "contraceptive vaccine" OR poison OR poisons OR poisoning OR rodenticide OR rodenticides OR "anticoagulant rodenticides" OR "first generation anticoagulant rodenticides" OR FGAR OR FGARS OR "second generation anticoagulant rodenticides" SGAR OR SGARs OR bromadiolone OR cis-bromadiolone OR brodifacoum OR difethialone OR chlorophacinone OR diphacinone OR flocoumafen OR warfarin OR coumatetralyl OR norbormide OR fumigant OR fumigants OR "alpha-chloralose" OR "alpha chloralose" OR

alphachloralose OR "hydrogen cyanide" OR phosphine OR "phosphine gas" OR strychnine OR "larsen trap" OR "larsen traps" OR "ladder trap" OR "ladder traps" OR "gin trap" OR "gin traps" OR "leg hold trap" OR "leg hold traps" OR "tunnel trap" OR "tunnel traps" OR "tunnel trapping" OR "trap barrier system" OR "trap barrier systems" OR "trojan female technique" OR "sterile male technique" OR "cranial dispatch" OR "cervical dislocation" OR removal OR "population removal" OR "population removals" OR eradication OR "rodent proofing" OR "pest proofing" OR falconry OR ferreting OR "conditioned taste aversion" OR "habitat modification" OR "habitat management" OR "scaring device" OR "olfactory inhibitors" OR "olfactory inhibitor" OR "electric fence" OR "leg cuff")

AND

("human wildlife conflict" OR "population control" OR "predator control" OR "predation impact" OR "predator impact" OR "nest predation" OR "wildlife management" OR conservation OR biosecurity OR "bovine tuberculosis" OR btb OR "environmental health" OR "crop damage" OR "crop protection" OR "protecting native species" OR "native species protection" OR "economic impact" OR "economic impacts"-OR "food hygiene" OR "disease prevention" OR "pest invasion" OR invasion OR reinvasion OR "alien invasion" OR vermin OR alien OR "target species" OR "alien species" vermin OR pest OR "invasive pests" OR "invasive pest" OR invasives)

AND

("target species" OR rodents OR rat OR rats OR "black rat" OR "ship rat" OR "ship rats" OR "rattus rattus" OR r.rattus OR "norway rat" OR "norway rats" OR "brown rat" OR "brown rats" OR "rattus norvegicus" OR r.norvegicus OR mouse OR mice OR murid* OR muroid*" OR "mus musculus" m.musculus OR "golden hamster" OR "golden hamsters" OR syrian hamster" OR "syrian hamsters" OR "mesocricetus auratus" OR m.auratus OR "prairie dog" OR "prairie dogs" OR "black tailed prairie dog" OR "black tailed prairie dogs" OR "cynomys ludovicianus" OR c.ludovicianus OR "edible dormouse" OR "edible dormice" OR "glis glis" OR g.glis OR "american mink" OR "neovison vison" OR n.vison OR muskrat OR muskrats OR "ondatra zibethicus" OR o.zibethicus OR "red deer" OR "cervus elaphus" OR c.elaphus OR "roe deer" OR "capreolus capreolus" OR c.capreolus OR "fallow deer" OR "dama dama" OR d.dama OR "muntjac deer" OR "muntiacus reevesi" OR m.reevesi OR "sika deer" OR "cervus nippon" OR c.nippon OR "Chinese water deer" OR "Hydropotes inermis" OR h.inermis OR "european rabbit" OR "european rabbits" OR rabbit OR rabbits OR "oryctolagus cuniculus" OR o.cuniculus OR mole OR moles OR "european mole" OR "european moles" OR "talpa europaea" OR t.europaea OR badger OR badgers OR "european badger" OR "european badgers" OR "meles meles" OR m.meles OR hedgehog OR hedgehogs OR "european hedgehog" OR "european hedgehogs" OR "erinaceus europaeus" OR e.europaeus OR stoat OR stoats OR "mustela erminea" OR m.erminea OR coypu OR "myocastor coypus" OR m.coypus OR porcupine OR porcupines OR "himalayan

porcupine" OR "himalayan porcupines" OR "hystrix hodgsonii" OR h.hodgsonii OR "hystrix brachyura" OR h.brachyura OR fox OR foxes OR "red fox" OR "red foxes" OR "vulpes Vulpes" OR v.vulpes OR squirrel OR squirrels OR "grey squirrel" OR "grey squirrels" OR "sciurus carolinensis" OR s.carolinesis OR hare OR hares OR "mountain hare" OR "mountain hares" OR "lepus timidus" OR l.timidus OR "brown hare" OR "brown hares" OR "european hare" OR "european hares" OR "lepus europaeus" OR l.europaeus OR weasel OR weasels OR "mustela nivalis" OR m.nivalis OR "wild boar" OR "wild boars" OR "sus scrofa" OR s.scrofa OR "eurasian beaver" OR "eurasian beavers" OR "european beaver" OR "european beavers" OR beaver OR beavers OR "castor fiber" OR c.fiber OR corvid OR crow OR "carrion crow" OR "corvus corone" OR c.corone OR "hooded crow" OR "corvus cornix" OR c.cornix OR jackdaw OR "corvus monedula" OR c.monedula OR jay OR "garrulus glandarius" OR g.glandarius OR magpie OR magpies OR "pica pica" OR p.pica OR raven OR ravens OR "corvus corax" OR c.corax OR rook OR rooks OR "corvus frugilegus" OR c.frugilegus OR pigeon OR pigeons OR "rock dove" OR "columba livia" OR c.livia OR "stock dove" OR "columba oenas" OR c.oenas OR dove OR doves OR "collard dove" OR "collard doves" OR "streptopelia decaocto" OR s.decaocto OR "wood pigeon" OR "wood pigeons" OR woodpigeon OR woodpigeons OR "columba palumbus" OR c.palumbus OR seagull OR seagulls OR "herring gull" OR "herring gulls" OR "larus argentatus" OR l.argentatus OR "lesser black backed gull" OR "lesser black backed gulls" OR "larus fuscus" OR l.fuscus OR "great black backed gull" OR "great black backed gulls" OR "larus marinus" OR l.marinus OR goose OR geese OR "greylag goose" OR "greylag geese" OR "anser anser" OR a.anser OR "egyptian goose" OR "egyptian geese" OR "alopochen aegyptiaca" OR a.aegyptiaca OR "canada goose" OR "canada geese" OR "branta canadensis" OR b.canadensis OR "ruddy duck" OR "ruddy ducks" OR "oxyura jamaicensis" OR o.jamaicensis OR parakeet OR parakeets OR "monk parakeet" OR "myiopsitta monachus" OR m.monachus OR "ring-necked parakeet" OR "ring-necked parakeets" OR "rose-ringed parakeet" OR "rose-ringed parakeets" OR "ring necked parakeet" OR "ring necked parakeets" OR "rose ringed parakeet" OR "rose ringed parakeets" OR "psittacula krameri" OR p.krameri OR starling OR starlings OR "european starling" OR "european starlings" OR "sturnus vulgaris" OR s.vulgaris OR sparrow OR sparrows OR "house sparrow" OR "house sparrows" OR "passer domesticus" OR p.domesticus OR buzzard OR "Buteo buteo" OR b.buteo OR "hen harrier" OR "hen harriers" OR "Circus cyaneus" OR c.cyaneus OR "grey seal" OR "Halichoerus grypus" OR h.grypus OR "common seal" OR "harbour seal" OR "Phoca vitulina" OR p.vitulina OR "feral cat" OR "felis catus" OR f.catus)

AND

("great Britain" OR GB OR "united kingdom" OR uk OR England OR "North East England" OR "Yorkshire and Humberside" OR "East of England" OR "East Anglia" OR "Eastern England" OR "The West country" OR Merseyside OR Scotland OR wales OR "Northern

Ireland" OR Hebrides OR Hebridean OR "outer hebrides" OR Orkneys OR "orkney islands" OR "Shetland Isles" OR Shetland)

Open Grey

•Because the complete search string is too long for this search engine, the population section is divided, and two searches carried out.

Search 1

◎ 70 results on 08/07/19

("spring trap" OR "spring traps" OR "live trap" OR "live traps" OR "glue trap" OR "glue traps" OR "sticky trap" OR "sticky traps" OR "scissor trap" OR "claw trap" OR "duffus trap" OR "talpa trap" OR "mole trap" OR translocation OR translocations OR cull OR culling OR shoot OR shooting OR hunt OR hunting OR stalking OR immunocontraception OR "contraceptive vaccine" OR poison OR poisons OR poisoning OR rodenticide OR rodenticides OR "anticoagulant rodenticides" OR "first generation anticoagulant rodenticides" OR FGAR OR FGARS OR "second generation anticoagulant rodenticides" SGAR OR SGARs OR bromadiolone OR cis-bromadiolone OR brodifacoum OR difethialone OR chlorophacinone OR diphacinone OR flocoumafen OR warfarin OR coumatetralyl OR norbormide OR fumigant OR fumigants OR "alpha-chloralose" OR "alpha chloralose" OR alphachloralose OR "hydrogen cyanide" OR phosphine OR "phosphine gas" OR strychnine OR "larsen trap" OR "larsen traps" OR "ladder trap" OR "ladder traps" OR "gin trap" OR "gin traps" OR "leg hold trap" OR "leg hold traps" OR "tunnel trap" OR "tunnel traps" OR "tunnel trapping" OR "trap barrier system" OR "trap barrier systems" OR "trojan female technique" OR "sterile male technique" OR "cranial dispatch" OR "cervical dislocation" OR removal OR "population removal" OR "population removals" OR eradication OR "rodent proofing" OR "pest proofing" OR falconry OR ferreting OR "conditioned taste aversion" OR "habitat modification" OR "habitat management" OR "scaring device" OR "olfactory inhibitors" OR "olfactory inhibitor" OR "electric fence" OR "leg cuff") AND ("human wildlife conflict" OR "population control" OR "predator control" OR "predation impact" OR "predator impact" OR "nest predation" OR "wildlife management" OR conservation OR biosecurity OR "bovine tuberculosis" OR btb OR "environmental health" OR "crop damage" OR "crop protection" OR "protecting native species" OR "native species protection" OR "economic impact" OR "economic impacts" OR "food hygiene" OR "disease prevention" OR "pest invasion" OR invasion OR reinvasion OR "alien invasion" OR vermin OR alien OR "target species" OR "alien species" vermin OR pest OR "invasive pests" OR "invasive pest" OR invasives) AND ("target species" OR rodents OR rat OR rats OR "black

rat" OR "ship rat" OR "ship rats" OR "rattus rattus" OR r.rattus OR "norway rat" OR "norway rats" OR "brown rat" OR "brown rats" OR "rattus norvegicus" OR r.norvegicus OR mouse OR mice OR murid* OR muroid*" OR "mus musculus" m.musculus OR "golden hamster" OR "golden hamsters" OR syrian hamster" OR "syrian hamsters" OR "mesocricetus auratus" OR m.auratus OR "prairie dog" OR "prairie dogs" OR "black tailed prairie dog" OR "black tailed prairie dogs" OR "cynomys ludovicianus" OR c.ludovicianus OR "edible dormouse" OR "edible dormice" OR "glis glis" OR g.glis OR "american mink" OR "neovison vison" OR n.vison OR muskrat OR muskrats OR "ondatra zibethicus" OR o.zibethicus OR "red deer" OR "cervus elaphus" OR c.elaphus OR "roe deer" OR "capreolus capreolus" OR c.capreolus OR "fallow deer" OR "dama dama" OR d.dama OR "muntjac deer" OR "muntiacus reevesi" OR m.reevesi OR "sika deer" OR "cervus nippon" OR c.nippon OR "Chinese water deer" OR "Hydropotes inermis" OR h.inermis OR "european rabbit" OR "european rabbits" OR rabbit OR rabbits OR "oryctolagus cuniculus" OR o.cuniculus OR mole OR moles OR "european mole" OR "european moles" OR "talpa europaea" OR t.europaea OR badger OR badgers OR "european badger" OR "european badgers" OR "meles meles" OR m.meles OR hedgehog OR hedgehogs OR "european hedgehog" OR "european hedgehogs" OR "erinaceus europaeus" OR e.europaeus OR stoat OR stoats OR "mustela erminea" OR m.erminea OR coypu OR "myocastor coypus" OR m.coypus OR porcupine OR porcupines OR "himalayan porcupine" OR "himalayan porcupines" OR "hystrix hodgsonii" OR h.hodgsonii OR "hystrix brachyura" OR h.brachyura OR fox OR foxes OR "red fox" OR "red foxes" OR "vulpes Vulpes" OR v.vulpes OR squirrel OR squirrels OR "grey squirrel" OR "grey squirrels" OR "sciurus carolinensis" OR s.carolinesis OR hare OR hares OR "mountain hare" OR "mountain hares" OR "lepus timidus" OR l.timidus OR "brown hare" OR "brown hares" OR "european hare" OR "european hares" OR "lepus europaeus" OR l.europaeus OR weasel OR weasels OR "mustela nivalis" OR m.nivalis OR "wild boar" OR "wild boars" OR "sus scrofa") AND ("great Britain" OR GB OR "united kingdom" OR uk OR England OR "North East England" OR "Yorkshire and Humberside" OR "East of England" OR "East Anglia" OR "Eastern England" OR "The West country" OR Merseyside OR Scotland OR wales OR "Northern Ireland" OR Hebrides OR Hebridean OR "outer hebrides" OR Orkneys OR "orkney islands" OR "Shetland Isles" OR Shetland)

Search 2

◎ 36 results on 08/07/19

("spring trap" OR "spring traps" OR "live trap" OR "live traps" OR "glue trap" OR "glue traps" OR "sticky trap" OR "sticky traps" OR "scissor trap" OR "claw trap" OR "duffus trap" OR "talpa trap" OR "mole trap" OR translocation OR translocations OR cull OR culling OR shoot OR shooting OR hunt OR hunting OR stalking OR immunocontraception

OR “contraceptive vaccine” OR poison OR poisons OR poisoning OR rodenticide OR rodenticides OR “anticoagulant rodenticides” OR “first generation anticoagulant rodenticides” OR FGAR OR FGARS OR “second generation anticoagulant rodenticides” SGAR OR SGARs OR bromadiolone OR cis-bromadiolone OR brodifacoum OR difethialone OR chlorophacinone OR diphacinone OR flocoumafen OR warfarin OR coumatetralyl OR norbormide OR fumigant OR fumigants OR “alpha-chloralose” OR “alpha chloralose” OR alphachloralose OR “hydrogen cyanide” OR phosphine OR “phosphine gas” OR strychnine OR “larsen trap” OR “larsen traps” OR “ladder trap” OR “ladder traps” OR “gin trap” OR “gin traps” OR “leg hold trap” OR “leg hold traps” OR “tunnel trap” OR “tunnel traps” OR “tunnel trapping” OR “trap barrier system” OR “trap barrier systems” OR “trojan female technique” OR “sterile male technique” OR “cranial dispatch” OR “cervical dislocation” OR removal OR “population removal” OR “population removals” OR eradication OR “rodent proofing” OR “pest proofing” OR falconry OR ferreting OR “conditioned taste aversion” OR “habitat modification” OR “habitat management” OR “scaring device” OR “olfactory inhibitors” OR “olfactory inhibitor” OR “electric fence” OR “leg cuff”) AND (“human wildlife conflict” OR “population control” OR “predator control” OR “predation impact” OR “predator impact” OR “nest predation” OR “wildlife management” OR conservation OR biosecurity OR “bovine tuberculosis” OR btb OR “environmental health” OR “crop damage” OR “crop protection” OR “protecting native species” OR “native species protection” OR “economic impact” OR “economic impacts” OR “food hygiene” OR “disease prevention” OR “pest invasion” OR invasion OR reinvasion OR “alien invasion” OR vermin OR alien OR “target species” OR “alien species” vermin OR pest OR “invasive pests” OR “invasive pest” OR invasives) AND (“target species” OR s.scrofa OR “eurasian beaver” OR “eurasian beavers” OR “european beaver” OR “european beavers” OR beaver OR beavers OR “castor fiber” OR c.fiber OR corvid OR crow OR “carrion crow” OR “corvus corone” OR c.corone OR “hooded crow” OR “corvus cornix” OR c.cornix OR jackdaw OR “corvus monedula” OR c.monedula OR jay OR “garrulus glandarius” OR g.glandarius OR magpie OR magpies OR “pica pica” OR p.pica OR raven OR ravens OR “corvus corax” OR c.corax OR rook OR rooks OR “corvus frugilegus” OR c.frugilegus OR pigeon OR pigeons OR “rock dove” OR “columba livia” OR c.livia OR “stock dove” OR “columba oenas” OR c.oenas OR dove OR doves OR “collard dove” OR “collard doves” OR “streptopelia decaocto” OR s.decaocto OR “wood pigeon” OR “wood pigeons” OR woodpigeon OR woodpigeons OR “columba palumbus” OR c.palumbus OR seagull OR seagulls OR “herring gull” OR “herring gulls” OR “larus argentatus” OR l.argentatus OR “lesser black backed gull” OR “lesser black backed gulls” OR “larus fuscus” OR l.fuscus OR “great black backed gull” OR “great black backed gulls” OR “larus marinus” OR l.marinus OR goose OR geese OR “greylag goose” OR “greylag geese” OR “anser anser” OR a.anser OR “egyptian goose” OR “egyptian geese” OR “alopochen aegyptiaca” OR a.aegyptiaca OR “canada goose” OR “canada geese” OR “branta canadensis” OR b.canadensis OR “ruddy duck” OR “ruddy ducks” OR “oxyura jamaicensis” OR o.jamaicensis OR parakeet OR parakeets OR “monk

parakeet" OR "myiopsitta monachus" OR m.monachus OR "ring-necked parakeet" OR "ring-necked parakeets" OR "rose-ringed parakeet" OR "rose-ringed parakeets" OR "ring necked parakeet" OR "ring necked parakeets" OR "rose ringed parakeet" OR "rose ringed parakeets" OR "psittacula krameri" OR p.krameri OR starling OR starlings OR "european starling" OR "european starlings" OR "sturnus vulgaris" OR s.vulgaris OR sparrow OR sparrows OR "house sparrow" OR "house sparrows" OR "passer domesticus" OR p.domesticus OR buzzard OR "Buteo buteo" OR b.buteo OR "hen harrier" OR "hen harriers" OR "Circus cyaneus" OR c.cyaneus OR "grey seal" OR "Halichoerus grypus" OR h.grypus OR "common seal" OR "harbour seal" OR "Phoca vitulina" OR p.vitulina OR "feral cat" OR "felis catus" OR f.catus) AND ("great Britain" OR GB OR "united kingdom" OR uk OR England OR "North East England" OR "Yorkshire and Humberside" OR "East of England" OR "East Anglia" OR "Eastern England" OR "The West country" OR Merseyside OR Scotland OR wales OR "Northern Ireland" OR Hebrides OR Hebridean OR "outer hebrides" OR Orkneys OR "orkney islands" OR "Shetland Isles" OR Shetland)

Defra Science and Research Projects Database 25/072019

- An initial search of the Defra website showed there was a limit of approximately 9 search terms which meant a complex search could not be carried out.
- A separate search of each species common name, species group (where appropriate, e.g.'rodents' or 'deer') was carried out; those with no results were discarded (Table 1).
- The remaining species or groups were searched with the terms (wildlife OR control OR management OR pesticide OR population OR conflict) (Table 2) to refine the search to population control reports (using terms for specific methods of control did not refine the search so was considered unnecessary).
- The results of each species/species group search will be screened to eliminate reports that did not cover population control.

Species and species groups eliminated from Defra search after yielding no results

Species common, latin or group names - eliminated from Defra database search after no results from search
Black rat
Rattus rattus
Rattus norvegicus
Murid*
Muroid*
Mus musculus
Golden hamster
Syrian hamster
Mesocricetus auratus

Black-tailed prairie dog/s
Cynomys ludovicianus
Edible dormouse
Glis glis
Neovison vison
Muskrat
Ondatra zibethicus
Cervus elaphus
Roe deer
Capreolus capreolus
Chinese water deer
Hydropotes inermis
Fallow deer
Dama dama
Muntjac
Muntiacus reevesi
Sika deer
Cervus nippon
Corvid
Carrion crow
Corvus corone
Hooded crow
Corvus cornix
Jackdaw
Corvus monedula
Garrulus glandarius
Pica pica
corvus corax
Corvus frugilegus
Oxyura jamaicensis
European rabbit/s
Oryctolagus cuniculus
European mole/s

Talpa europaea
Hedgehog/s
European hedgehog
0Erinaceus europaeus
Stoat/s
Mustela erminea
Coypu

Myocastor coypus
Himalayan porcupine
Hystrix hodgsonii or Hystrix brachyura
Vulpes vulpes
Sciurus carolinensis
Mountain hare
Lepus timidus
European hare
Lepus europaeus
Weasel/s
Mustela nivalis
Rock dove
Columba livia
Stock dove
Columba oenas
Columba palumbus
Collared dove
Streptopelia decaocto
Seagull/s
Herring gull

Species and Species groups retained for final search of the Defra database

Species/family	**Best search string**	**Defra database 21/07/19**
Target species	"target species"AND (wildlife OR control OR management OR pesticide OR population OR conflict)	0
Rodents	rodent OR rodents OR rats AND (wildlife OR control OR management OR pesticide OR population OR conflict)	31
Norway rat	"norway rat" OR "norway rats" AND (wildlife OR control OR management OR pesticide OR population OR conflict)	1
American mink	american mink OR mink AND (wildlife OR control OR management OR pesticide OR population OR conflict)	0
Mouse/mice	Mouse or mice AND (wildlife OR control OR management OR pesticide OR population OR conflict)	10
Jay	Jay AND (wildlife OR control OR management OR pesticide OR population OR conflict)	1
Magpie/s	magpie OR magpies AND (wildlife OR control OR management OR pesticide OR population OR conflict)	1
Ruddy duck	"ruddy duck" AND (wildlife OR control OR management OR pesticide OR population OR conflict)	1

Squirrel/s	squirrel OR squirrels AND (wildlife OR control OR management OR pesticide OR population OR conflict)	2
European badger/s	"european badger" OR "european badgers" AND (wildlife OR control OR management OR pesticide OR population OR conflict)	1
rabbit	rabbit or rabbits AND (wildlife OR control OR management OR pesticide OR population OR conflict)	38
Badgers	Badger or badgers AND (wildlife OR control OR management OR pesticide OR population OR conflict)	111
Foxes	Fox or foxes AND (wildlife OR control OR management OR pesticide OR population OR conflict)	10
Feral cats	(cat OR cats) AND (wildlife OR control OR management OR pesticide OR population OR conflict)	186
Starlings	Starling AND (wildlife OR control OR management OR pesticide OR population OR conflict)	0
Sparrows	Sparrow OR sparrows AND (wildlife OR control OR management OR pesticide OR population OR conflict)	1
Hen harrier	"hen harrier" AND (wildlife OR control OR management OR pesticide OR population OR conflict)	0

Northern Ireland Assembly Research Publications

- http://www.niassembly.gov.uk/assembly-business/research-and-information-service-raise/research-publications/
- The database doesn't have an advanced feature but there are only a small number of publications per year so each species will be searched individually and results will be screened for reports that fit the inclusion criteria.

Named species search of the Northern Ireland Assembly Research Publications

SC 3 – (population) - species/group	**Search**	**NI Assembly results**
Target species	"target species"	4
Rodent/s	rodent OR rodents	1
Rat/s	rat OR rats	4
Black rat	"black rat" OR "black rats" OR "ship rat" OR "ship rats"	0
Rattus rattus	"rattus rattus" OR "r.rattus"	0
Norway rat	"norway rat" OR "norway rats"	0
Brown rat/s	"brown rat" OR brown rats"	0
Rattus norvegicus	"rattus norvegicus" OR "r.norvegicus"	0
Mouse	mouse	2
Mice	mice	2
Murid*	murid	0
Muroid*	muroid	0
Mus musculus	"mus musculus"	0
Hamster	hamster OR hamsters	1
Syrian hamster	"syrian hamster"	0
Golden hamster	"golden hamster"	0
Mesocricetus auratus	"mesocricetus auratus"	0
Black-tailed prairie dog/s	"black prairie dog OR black-tailed prairie dogs"	0
Cynomys ludovicianus	"cynomys ludovicianus"	0
Edible dormouse	"edible dormouse" OR "edible dormice""	0
Glis glis	"glis glis"	0
American mink	"american mink"	0
Neovison vison	"neovison vison"	0
Muskrat	muskrat OR muskrats	0
Ondatra zibethicus	"ondatra zibethicus"	0
Red deer	"red deer"	1

Cervus elaphus	"cervus elaphus"	0
Roe deer	"roe deer"	0
Capreolus capreolus	"capreolus capreolus"	0
Chinese water deer	"chinese water deer"	0
Hydropotes inermis	“hydropotes inermis”	0
Fallow deer	"fallow deer"	0
Dama dama	"dama dama"	0
Muntjac	muntjac	0
Muntiacus reevesi	"muntiacus reevesi"	0
Sika deer	"sika deer"	2
Cervus nippon	"cervus nippon"	0
Corvid	corvid OR corvids	0
Crow/s	crow OR crows	7
Carrion crow	"carrion crow" OR "carrion crows"	0
Corvus corone	"corvus corone"	0
Hooded crow	"hooded crow" OR "hooded crows"	0
Corvus cornix	"corvus cornix"	0
Jackdaw	jackdaw OR jackdaws	0
Corvus monedula	"corvus monedula"	0
Jay	jay	0
Garrulus glandarius	"garrulus glandarius"	0
Magpie/s	magpie OR magpies	0
Pica pica	"pica pica"	0
Raven/s	raven OR ravens	0
corvus corax	"corvus corax"	0
Rook/s	rook OR rooks	0
Corvus frugilegus	“corvus frugilegus”	0
Ruddy duck	"ruddy duck"	0
Oxyura jamaicensis	"oxyura jamaicensis"	0
Rabbit/s	rabbit OR rabbits	1
European rabbit/s	"european rabbit" OR "european rabbits"	0
Oryctolagus cuniculus	"oryctolagus cuniculus"	0
European mole/s	"european mole" OR "european moles"	0
Mole/s	mole OR moles	3
Talpa europaea	"talpa europaea"	0
European badger/s	"european badger" OR "european badgers"	0
Badger/s	badger OR badgers	10
Meles meles	"meles meles"	1
Hedgehog/s	hedgehog OR hedgehogs	0

European hedgehog	“european hedgehog" OR "european hedgehogs"	0
0Erinaceus europaeus	"erinaceus europaeus"	0
Stoat/s	stoat OR stoats	0
Mustela erminea	"mustela erminea"	0
Coypu	coypu	0
Myocastor coypus	"myocastor coypus"	0
Himalayan porcupine	“himalayan porcupine" OR "himalayan porcupines”	0
Hystrix hodgsonii or Hystrix brachyura	“hystrix hodgsonii” OR "hystrix brachyura”	0
Fox/es	fox OR foxes	466
Red fox/es	"red fox" OR "red foxes"	0
Vulpes vulpes	"vulpes vulpes"	0
Squirrel/s	squirrel OR squirrels	2
Sciurus carolinensis	"sciurus carolinensis"	1
Hare	hare OR hares	6
Mountain hare	"mountain hare" OR "mountain hares"	1
Lepus timidus	"lepus timidus"	1
European hare	"european hare" OR "european hares"	6
Brown hare	"brown hare" OR "brown hares"	1
Lepus europaeus	"lepus europaeus"	0
Weasel/s	weasel OR weasels	0
Mustela nivalis	"mustela nivalis"	0
Wild boar	"wild boar"	0
Sus scrofa	"sus scrofa"	0
Pigeon	pigeon OR pigeons	3
Rock dove	"rock dove" OR "rock doves"	0
Columba livia	"columba livia"	0
Stock dove	"stock dove" OR "stock doves"	0
Columba oenas	"columba oenas"	0
Wood pigeon	"wood pigeon" OR "wood pigeons" OR woodpigeon OR woodpigeons	0
Columba palumbus	"columba palumbus"	0
Collared dove	"collared dove" OR "collared doves"	
Streptopelia decaocto	"streptopelia decaocto"	0
Seagull/s	seagull OR seagulls	0
Herring gull	"herring gull" OR "herring gulls"	0
Larus argentatus	"larus argentatus"	0

Lesser black backed gull	"lesser black backed gull" OR "lesser black backed gulls"	0
Larus fuscus	"larus fuscus"	0
Canada goose/geese	"canada goose" OR "canada geese"	0
branta canadensis	"branta canadensis"	0
Greylag goose/geese	"greylag goose" OR "greylag geese"	0
Anser anser	"anser anser"	0
Egyptian goose/geese	"egyptian goose" OR "egyptian geese"	0
Alopochen aegyptiaca	"alopochen aegyptiaca"	0
Parakeet	parakeet OR parakeets	0
Monk parakeet	"monk parakeet" OR "monk parakeets"	0
Myiopsitta monachus	"myiopsitta monachus"	0
Ring necked parakeets	“ring-necked parakeet” OR “ring-necked parakeets”	0
Psittacula krameri	“psittacula krameri”	0
Beaver	beaver OR beavers	1
Castor fiber	“castor fiber”	0
Starling/s	starling OR starlings	0
European starling/s	"european starling" OR "european starlings"	0
Sturnus vulgaris	"sturnus vulgaris"	0
Sparrow/s	sparrow OR sparrows	0
Passer domesticus	"passer domesticus"	0
Buzzard/s	buzzard OR buzzards	0
Buteo buteo	"buteo buteo"	0
Hen harrier/s	“hen harrier” OR “hen harriers”	1
Circus cyaneus	“circus cyaneus”	0
Grey seal/s	"grey seal" OR "grey seals"	0
Halichoerus grypus	"halichoerus grypus"	0
Common seal/s	"common seal" OR "common seals"	0
Harbour seal/s	"harbour seal" OR "harbour seals"	0
Phoca vitulina	"phoca vitulina"	0
Feral cat	"feral cat"	0
felis catus	"felis catus"	0

SC 3 – (population) - species/group	**Search**	**NI Assembly results**
Target species	"target species"	4
Rodent/s	rodent OR rodents	1
Rat/s	rat OR rats	4
Mouse/mice	mouse OR mice	2
Red deer	"red deer"	1
Sika deer	"sika deer"	2
Crow/s	"crow OR crows"	7
Rabbit/s	rabbit OR rabbits	1
Mole/s	mole OR moles	3
Badger/s	badger OR badgers OR “meles meles”	10
Fox/es	fox OR foxes	12
Squirrel/s	squirrel OR squirrels OR "sciurus carolinensis"	2
Hare	hare OR hares OR "mountain hare" OR "mountain hares" OR "lepus timidus" OR "european hare" OR "european hares" OR "brown hare" OR "brown hares"	6
Pigeon	pigeon OR pigeons	3
Beaver	beaver OR beavers	1

Supplementary Information 2

Inclusion and exclusion criteria

This field of research required access not only to published scientific journals, but also government research and unpublished academic theses [1]. It was of particular interest to access government research as these papers are written directly for policy makers [2]. Web of Science (WOS) and EBSCO were identified as databases that would yield a comprehensive range of published literature and were available through the university subscription. Open Grey provided access to unpublished doctoral theses [3]. Advice was sought from the regional government departments to identify the best sources for their research, these were the DEFRA Science and Research database (England, Wales and Scotland) [4] and the Northern Ireland (NI) Assembly Research and Information Service [5]. Documents that could not be obtained via the university subscriptions, were obtained directly from authors or through inter library loans.

Inclusion and exclusion criteria were guided by the PICOS (Population, Intervention, Comparison, Outcome, Study design) approach (Table 3) [6,7]. The literature review provided search terms relevant to each PICOS category. It was necessary to develop different approaches for each database; the DEFRA and NI Assembly databases were not able to accommodate long search strings, so searches were complex. Searches were carried out and texts screened according to the inclusion and exclusion criteria. Initial screening of titles and abstracts was followed by full text screening.

Table 1 Inclusion and exclusion criteria (PICOS)

PICOS	Inclusion and exclusion criteria
Population	Inclusion criteria: Bird or mammal species
	Exclusion criteria: Invertebrate species; species not subject to population control.
Intervention	Inclusion criteria: Any lethal or non-lethal method of controlling wild populations of animals
	Exclusion criteria: Interventions not used for wildlife population control
Comparison	N/A
Outcome	Inclusion criteria: Descriptive language and imagery used to describe species subject to control, the element to be protected and the aims of the study
	Exclusion criteria: descriptive language and imagery used to describe other factors
Study design	Inclusion criteria: All original field studies where the objective of the study is wildlife population control for pest control or conservation
	Exclusion criteria: Reviews. Studies that are not directly controlling a wildlife population; Laboratory trials of population control methods
Other restrictions	
Language	Inclusion criteria: English language
	Exclusion criteria: Any other language and translations into English
Publication date	Inclusion criteria: All
	Exclusion criteria: None
Region	Inclusion criteria: Geographical restriction to the UK
	Exclusion criteria: Studies outside the UK

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Supplementary Information 3

Quality Assessment

Mupepele et al., (2014)'s quality assessment format (designed for conservation studies) was adapted and used to assess the included papers [1]. This method grades the Level of Evidence (LoE) on a hierarchy from weak to strong (Figure 1). An initial level was designated corresponding to study design, then a series of questions (Table 1) generated a score, and the LoE was adjusted (Table 2) accordingly. The example (Table 1) shows the study only achieved 67% of the relevant criteria, in this study, the main deficits were in reporting the analysis; as Table 6 shows a score between 60 and 79% means the LoE should be adjusted one half level down, in this case from LoE2a to LoE2b).

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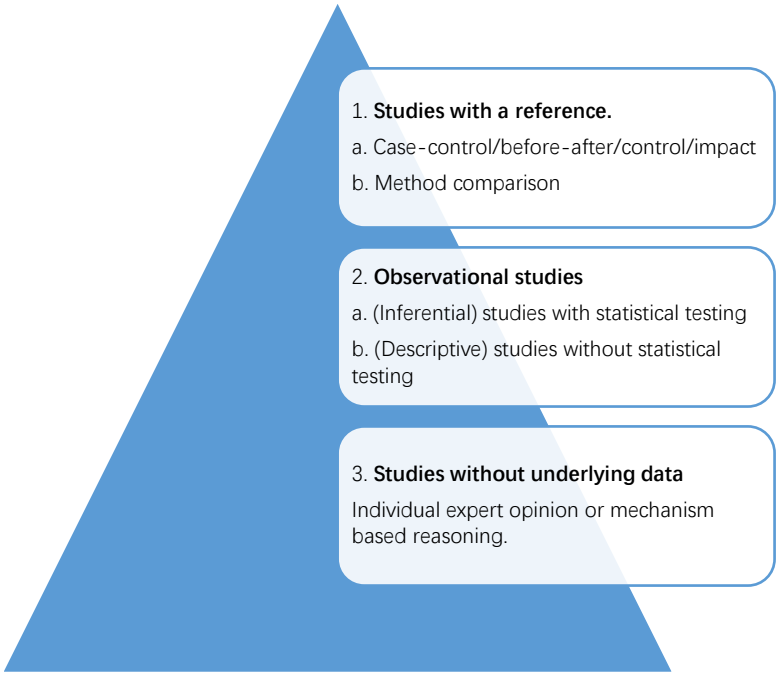

Figure 1Hierarchy of study designs from stronger (top) to weaker (bottom) evidence, adapted from (Mupepele et al., 2014)

Table 1 Quality assessment checklist with example; adapted from (Mupepele *et al.*, 2014)

Quality Assessment Checklist	
Study information	
Study ID	REN75
Reference	Rennison and Hadler (1975)
Research Question	Field trials of warfarin vs two concentrations of difenacoum anticoagulant rodenticide
Outcome	Warfarin failed to reduce populations where there were resistant animals Difenacoum controlled populations faster than warfarin at farms where there were non-resistant animals. Control using difenacoum took longer where there were warfarin resistant animals and where there

	were abundant food sources. Lower concentrations of difenacoum were as effective as higher concentrations.
Study design - Level of Evidence	Treatment comparison, no control LoE2a
Section 2: Checklist	
Research aim questions	
1. Does the study address a clearly focused question?	Y
2. Does the question match the answer?	Y
Data collection	
3. Was the population/area of interest defined in space, time and size?	N
4. Selection bias: Was the sample area representative for the population defined?	Y
5. Was the sample size appropriate?	Y
6. Was probability/random sampling used for constructing the sample?	n/a
7. Were the data collection methods described in sufficient detail to permit replication?	Y
Analysis	
8. Were the statistical/analytical methods described in sufficient detail to permit replication?	N
9. Is the choice of statistical/analytical methods appropriate and/or justified?	N
10. Was uncertainty assessed and reported?	N
Results and Conclusions	
11. Do the data support the outcome?	Y
12. Magnitude of effect: Is the effect large, significant and/or without large uncertainty?	N
13. Are all variables and statistical measures reported?	N
14. Attrition bias: Are non-response/dropouts given and is their impact discussed?	Y
Study with a reference/control	
15. Allocation bias: Was the assignment of treatment-control groups randomised?	n/a
16. Were groups designed equally, aside from the investigated point of interest?	N
17. Performance bias: Was the sampling blinded?	n/a
18. Were there sufficient replicates of treatment and reference groups?	Y

19. Detection bias: Were outcomes equally measured and determined between groups?	Y
20. Were confounding factors identified and strategies to deal with them stated?	Y
Quantification	
21. Is the unit of the quantification measurement appropriate?	Y
22. Was temporal change (e.g. annual or long-term) of quantities measured (e.g. species abundance or an ecosystem service) discussed?	Y
Management	
23. Was the aim of the management intervention clearly defined?	Y
24. Were side effects and trade-offs on other non-target species, ecosystem services or stakeholders considered?	N
25. Were both long-term and short-term effects discussed?	Y
26. Did monitoring take place for an appropriate time period?	Y
27. Appropriate outcome measures: Are all relevant outcomes measured in a reliable way?	Y
Section 3: Score	
Total points	16
Possible points	24
Score (%)	67%
Adjusted LoE	LoE2b

Table 2 Quality assessment adjustment guide adapted from (Mupepele et al 2014)

Score	**Adjustment**
80-100%	No adjustment
60-79%	Half level adjustment
40-59%	1 level adjustment
20-39%	1 ½ level adjustment
0-20%	Invalid study

References

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