Identifying and prioritising conflicts between human and wildlife interests in Great Britain

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Abstract

We reviewed the scientific literature to identify human-wildlife conflicts associated with British terrestrial mammals to summarise their magnitude and, where possible, costs. Conflicts were classified as either economic, health, environmental or social, further divided into 32 subcategories. We applied a Generic Impact Scoring System (GISS), whereby individual conflicts were scored on a scale of 1-5 (minimal to highest known impact); these were used to determine the potential impact (sum of all conflicts) and actual impact (sum of all conflicts corrected for geographical distribution) of individual mammals so they could be ranked on their level of impact. Forty-eight mammals were involved in a total of 200 separate conflicts. The highest ranked conflicts (scoring 5) were all measurable on an economic scale (involving rabbit, badger, brown rat and grey squirrel). We estimated a conservative annual economic cost of human-wildlife conflicts in excess of £0.5 billion, which could exceed £1 billion if health and environmental conflicts could be monetarised. The most common conflicts were health related (reservoir of disease and zoonotic disease), although generally, health conflicts were scored low (mostly 1 or 2). Overall, there was no statistical difference in impact score depending on status (native or non-native); however, when considered by subcategory, non-native species scored higher in relation to damage to woodland, agricultural interests and property, and reservoir of zoonotic disease, whilst native species caused more conflict with construction and development, and predation of livestock. Non-native species had a higher potential impact score compared to native species, but not actual impact. However, actual impact was predicted to increase, relative to population size, at a higher rate for non-native species compared to native, highlighting the need for surveillance and monitoring. Where mammals represent a

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cost to some, they may provide a benefit to others, e.g. fox predation of rabbits, and as such may require a holistic approach to management. We concluded that a GISS approach is a useful tool for identifying conflict species and could form part of a package of measures to ensure a balance between the need to conserve and enhance biodiversity, whilst also considering the interests of those directly affected by human-wildlife conflict, is achieved.

Introduction

Co-habitation between humans and wildlife occurs on more than half of the earth's surface [1] and consequently human-wildlife interactions form an integral part of many ecosystems worldwide. Interactions between people and wildlife are often varied and complex and whilst the presence of wildlife may have beneficial impacts on human interests, there is a continued focus on conflict narratives that dominates how human-wildlife interactions are viewed [2].

Human-wildlife conflict is commonly described as conflict occurring between people and wildlife [3], presence and/or actions of humans or wildlife that have an adverse effect on the other [4] or threats posed by wildlife to economic activities, human life, recreation [5] or ecosystem services. Factors such as the intensification of agriculture and increasing human population have had major impacts on ecosystems worldwide [6]. Agricultural growth is expected to accelerate, resulting in an increase in farmland and subsequent decrease in the available habitat for wildlife [7]. Wildlife damage to crops is often cited as a major global conflict [3, 8, 9], which will continue to worsen as habitat loss precipitates an increase in human-wildlife encounters. Population growth and habitat encroachment may also increase the risk of disease transmission, which is of particular concern where wildlife pose zoonotic risks. For

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example, the first human cases of severe acute respiratory syndrome coronavirus (SARS-CoV) in Guangdong province, China, in 2002, were linked to wildlife found at a live animal market [10, 11]. Subsequent serological surveys from residents living close to bat caves in Yunnan, China, which is geographically disparate to Guangdong, were found to be positive for SARS-related coronavirus (SARSr-CoV), indicating that spillover events may have occurred in zoonotic CoVs [12].

Conflict issues can arise with several types of problematic species, including native pests, invasive native species and invasive non-native species [13]. These often induce debates on how or whether humans and wildlife can co-exist [7], and may involve complex decisions where the conservation status of a species conflicts with its impacts on humans [3]. Addressing and categorising the adverse effects of human-wildlife conflicts is recognised as a challenging issue for conservation and development efforts [14]. There is a general consensus that the negative effects created by some wildlife species, particularly invasive non-native species, have to be reduced [15]. Where conflicts arise between wildlife and human interests, there is often the need to intervene to reduce or mitigate the impacts and therefore identifying what conflicts are occurring and what their impacts are is essential for informing decision-making and resource allocation [16]. In 2022, the UK agreed to a global policy framework at the Conference of Parties (COP15) to the Convention on Biological Diversity that created a package of international measures to address the loss of global biodiversity and to restore natural ecosystems. One of the targets identified for reducing threats to biodiversity was managing human-wildlife conflicts, which in turn would feed into other elements of the framework, such as enhancing sustainability in agriculture, fisheries and forestry [17]. However, identifying which species are causing

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89 conflict and subsequently which should be targeted first can be challenging and
90 controversial [15].

91 Invasive non-native species are a major threat to biodiversity worldwide, severely
92 impacting areas of high endemism [18], whilst also posing a serious threat to public
93 health and economic activities. As of 2019, 3,224 plants and animals had been
94 introduced to Great Britain, costing the UK economy almost £4 billion annually [16];
95 10-15% of these are considered invasive with an estimated 188 invasive non-native
96 animals recorded in 2020 [19]. Tackling invasive non-native species is a key part of
97 achieving the UK government's aims under its 25-year Environment plan [20] as well
98 as the UK's obligation as a signatory of the Convention on Biological Diversity
99 (https://www.cbd.int/convention/text/). However, even managing conflict caused by
100 invasive non-native species can be controversial, resulting in debates on achievability,
101 efficiency, social fairness and ethical implications [21]. For example, the removal of
102 hedgehogs from South Uist, where they were introduced to control garden pests but
103 consequently contributed significantly to the decline of wading shorebirds [22] resulted
104 in widespread criticism and opposition, given that hedgehogs are a popular icon of
105 British wildlife and are thought to be declining nationally [21].

106 Much of the available literature on wildlife conflicts in the UK, both in terms of
107 economic and biodiversity impacts, focuses on invasive non-native species [e.g. 16,
108 23]. However, there is evidence to suggest that the most invasive non-native species
109 are not necessarily the most damaging [24, 25], therefore there is the need to consider
110 also the impacts of native species, some of which can cause considerable human-
111 wildlife conflict. For example, badgers are a known reservoir host of *Mycobacterium*
112 *bovis*, the causative agent of bovine tuberculosis, which poses a risk to livestock health
113 and is a serious economic problem for the UK cattle industry [26]. Issues such as this

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highlight the challenge of conflict resolution for iconic British species, which can be both controversial and associated with complex legislative considerations. It is necessary, however, to consider all problematic species to address the UK's commitments to improving biodiversity as part of government plans or global policy frameworks.

Whilst policy frameworks are essential for providing goals and targets to reverse biodiversity loss, they do not necessarily incorporate a process by which these targets, such as managing human-wildlife conflict, can be identified in the first place, nor which should be prioritised. Assessing conflicts between species is further complicated by the fact that impacts are context dependent [27], which requires that the measure of impact is standardised to quantify and compare differences between species, taxonomic groups and localities [28]. When addressing the biodiversity impacts of invasive non-native species, Nentwig et al. [15] suggested prioritising actions against the alien species with a high impact potential of becoming established or spreading, using a method to quantify impacts in a way that could be compared among alien species within a taxonomic group. They devised a generic impact scoring system (GISS) to compare relevant impact categories that had been reported in the scientific literature, applying a scoring system to quantify impacts within the categories and rank species according to their impact scores. The GISS has since been modified and applied to a variety of classifications including alien fish [29], terrestrial arthropods [30], aquatic invertebrates [31], plants [32, 33] and alien birds [34].

The main aim of this paper was to identify and categorise human-wildlife conflicts associated with British mammals in order to summarise their magnitude and, where possible, their costs. The research augmented a review of human-wildlife conflicts produced over a decade ago (APHA, unpublished data) in response to a now

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withdrawn Defra policy framework on Wildlife Management in England [35]. Only terrestrial mammals (including bats) were assessed as they involve some of the most controversial and sensitive issues as well as complex legislative considerations. To determine whether the available evidence reflected the level of risk to human interests, or the welfare or conservation status of an affected species, a modified GISS was applied to all conflicts so that mammals could be ranked according to their level of impact. Identifying species with the highest impact scores has the potential to assist policy development by enabling prioritisation of the most damaging species. In addition, the compilation of a comprehensive audit of British wildlife conflicts highlights where further areas of research might be required and identifies the early emergence of potential issues.

Materials and methods

Literature searches and screening

Searches were undertaken using Scopus (an abstract and citation database of peer-reviewed scientific literature) for literature published up until and including 2024. Additional searches were conducted using Google Scholar limited to the first 200 returns [36] to provide additional evidence where required. Separate searches were carried out for each of the 66 terrestrial mammals incorporating a combination of unique species terms and common keywords within the title, abstract and keywords of the scientific literature. The following search terms were applied to each species: [{common name} AND {Latin name}] AND [{England} OR {Scotland} OR {Wales} OR {Great Britain} OR] AND [{conflict} OR {pest} OR {damage} OR {impact} OR {management} OR {disease} OR {zoono*} OR {animal health} OR {health} OR {conservation} OR {predat*}]. The minimum requirements for a literature resource to

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be included in the analysis were the presence of an accessible abstract and that the conflict occurred in Great Britain. Only articles written in English were included.

All articles returned during an individual search were subjected to a number of screening processes. A rapid first screening of the title assessed documents for any likely relevance to the species concerned and its potential conflicts. All potentially relevant articles or ambiguous titles were screened further by examining the abstracts in more detail or the full article, if necessary, resulting in a definitive list of conflicts for each species. In many cases, single articles were applicable to multiple conflicts and/or more than one species and therefore may have been added retrospectively to a species reference catalogue.

Categorising and scoring conflicts

Conflicts were categorised depending on whether they were an economic, health, environmental or social impact. Within these four main categories, conflicts were further assigned to 32 subcategories (economic=15, health=6, environmental=7, social=4). Subcategories were not weighted, therefore all subcategories were considered as of equal importance. Some species were involved in multiple conflicts within multiple categories, which were all captured as distinct entities. A comprehensive report was compiled for all species identified as being involved in human-wildlife conflict. An impact scale scoring system modified from Nentwig et al. [15] was applied to estimate the magnitude of each conflict at the national level for Great Britain, rated independently by three reviewers (KP, DC, GS). The level of impact was quantified on a scale of 1 (minimal impact known) to 5 (the highest possible impact: Table 1), with a value of confidence (low=1, medium=2 or high=3: Table 2) also assigned to each conflict (taken from Hawkins et al. [37]). Mammals for which no

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data were available, no impacts were known or impacts were not detectable were excluded from the analysis. The median of the three independent assignments of impact scale and confidence rating are reported for each conflict.

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Table 1. Criteria used to describe the scale of impacts in each of the four categories of conflict.

Scale of impact	A. Economic impact	B. Health impact	C. Environmental impact	D. Social impact
1	<£10K / yr	Local mild, short-term, reversible effects to individuals	Local, short-term, population loss, no significant ecosystem effect	Minimal social disruption
2	£10K – 100K / yr	Mild short-term, reversible effects to identifiable groups, localised	Some ecosystem impact, reversible changes, localised	Significant concern expressed at local level
3	£100K – 1M / yr	Minor irreversible effects and/or larger numbers covered by reversible effects, localised	Measurable long-term damage to populations and ecosystem, but little spread, no extinction	Temporary changes to normal activities at local level
4	£1M – 10M / yr	Significant irreversible effects locally or reversible effects over a large area	Long-term irreversible ecosystem change, spreading beyond local area	Some permanent change of activity locally, concern over a wider area
5	>£10M / yr	Widespread, severe, long-term, irreversible health effects	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Long-term social change, significant loss of employment, migration from area

Table 2. Criteria used for the confidence ratings of the impact scale assignments.

Confidence level	Example evidence
High (3) (approx. 90% chance of impact scale assignment being correct)	There is direct relevant observational evidence to support the assessment; **and** Impacts are recorded at the typical spatial scale over which the conflict can be characterised; **and** There are reliable / good quality data sources on the impacts of the conflict; **and** The interpretation of the data / information is straightforward; **and** Data / information is not controversial or contradictory
Medium (2) (approx. 65-75% chance of impact scale assignment being correct)	There is some direct observational evidence to support the assessment but some information is inferred; **and/or** Impacts are recorded at a spatial scale, which may not be relevant to the scale over which conflict can be characterized, but extrapolation or downscaling of the data to relevant scales is considered reliable, or to embrace little uncertainty; **and/or** The interpretation of the data is to some extent ambiguous or contradictory
Low (1) (approx. 35% chance of impact scale assignment being correct)	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence; **and/or** Impacts are recorded at a spatial scale, which is unlikely to be relevant to the scale over which conflict can be characterized; extrapolation or downscaling of the data to relevant scales is considered unreliable potentially leading to significant uncertainties; **and/or** Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous; **and/or** The information sources are considered to be of low quality or contain information that is unreliable

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198 Various species characteristics were also included in the analyses to determine
199 whether they were associated with a conflict impact (modified from Nentwig et al. [15]).
200 Impact scores were considered as the maximum impact for a particular species in
201 Great Britain and did not account for their current distribution. Overall impacts were
202 compared between species by summing the median scores of all conflicts and within
203 each category ("potential impact"). To consider the distribution of a species, potential
204 impact values were multiplied by the proportion of hectads (10 kilometre square
205 resolution) each species occupies in Great Britain (derived from Crawley et al. [38]).
206 The potential impact scores, corrected for the area occupied can be considered as the
207 "actual impact" a species causes in Great Britain. Estimated population sizes were
208 derived mostly from Mathews et al. [39], typical body weights were taken mostly from
209 Harris & Yalden [40]. Where information was missing, relevant online sources were
210 used (see S2 Table). The overall biomass for each species was calculated by
211 multiplying population estimates and body mass. Population estimates and/or
212 distribution data could not be reliably established for three species (feral cat, feral
213 ferret, greater white-toothed shrew), therefore they were excluded from some of the
214 statistical analyses.

215 Statistical analysis

216 All statistical analyses were performed using the R statistical programme version 4.2.2
217 [41] and the RStudio Integrated Development Environment (IDE: version 2022.12.0,
218 Posit Software, PBC). Given the nature of the response variables, initial analyses (to
219 assess whether impact/confidence scores assigned by the three reviewers differed
220 overall and in relation to the conflict species assessed) were performed using an
221 ordinal logistic regression model fitted using the *ordinal::clm* function version 2023.12-

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4. [42]. Species were aggregated based on status (native/non-native/feral) and taxonomic order, with an interaction term between each aggregate type and reviewer ID included. Additional analyses were performed to assess whether impact scores assigned by the reviewers differed across impact categories (i.e. economic, environmental, health and social), across subcategories, between native/non-native species and between taxonomic orders, including interaction terms. (N.B. feral species were removed from further analyses due to their low number of conflicts). Data were expanded to account for the disparity in the number of subcategories described for each species from the literature, so that for each species, a total of 32 subcategories were present, with an impact and confidence score of zero (0), representing no available data, assigned to absent subcategories.

Differences in potential and actual impact scores were analysed using generalised linear models (GLM), using the *glmmTMB* package version 1.1.10 [43]. Diagnostic testing of these analyses was performed using the *DHARMa* package version 0.4.7 [44]. Prior to analysis, data were modified to account for species whereby an actual impact score could not be reliably established, with a score of zero (0) assigned to indicate insufficient evidence of impact. Feral ferret was subsequently excluded from the analyses, given a lack of data regarding population size and geographic distribution. Analyses assessed whether estimates of total impact (actual or potential) differed in relation to native/non-native status and taxonomic order, when modelled independently. Several covariate predictors were also specified independently in each model, including population size, body mass (kg) and biomass (kg). Models consisted of GLMs, fitted with a gaussian error distribution and “identity” link function, selected given that model residuals conformed to key assumptions (i.e. linearity, normality, homogeneity of variance), when total impact estimates were logarithmically

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transformed [log(n+1)]. For each model, a two-way interaction term was specified between species aggregation type (either native/non-native status or taxonomic order) and each covariate predictor (population size, body mass, biomass). Due to issues with model performance, population size, body mass and biomass were also log-transformed [log(n+1)].

Additional analyses examined how estimates of impact (actual or potential) might differ across the main impact categories (economic, health, environment, social); these were performed using a GLM fitted with a Tweedie distribution, which is appropriate when analysing a continuous response variable consisting of a combination of zeroes and positive values. These models compared impact across categories in relation to native/non-native status and order, as well as population size, body mass and biomass. Interaction terms involving impact category, species aggregation type and each covariate predictor were included with respect to native/non-native species only. Analyses of impact, in relation to impact categories and order and covariate predictors, were limited to main order effects only, due to persistent issues with model performance (i.e. failure of models to converge), when considering any possible interaction between both predictor variables. This is likely due to the complexity of the models (impact category=4 levels; taxonomic order=6 levels; total number of factorial combinations=24) when considering interaction terms and the complete separation of certain impact categories across certain taxonomic orders, caused by the presence of absolute zeroes (e.g. social impact and Rodentia).

Results

General literature searches

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A total of 13,148 articles were returned for potential human-wildlife conflicts involving the 66 terrestrial mammals in the UK. Further screening identified 405 useful articles for 48 mammals belonging to seven taxonomic groups (Rodentia: n=15; Carnivora: n=11; Artiodactyla: n=8; Chiroptera: n=6; Eulipotyphla: n=4; Lagomorpha: n=3; Perissodactyla: n=1). The first available record was from 1947 and the latest was from 2024. The majority of articles (n=367, 91%) were published within the last three decades (2014-2024: n=176, 44%; 2004-2013: n=110, 27%; 1994-2003: n=81, 20%).

A detailed description of all of the conflicts is in S1 File. A summary of characteristics (native/non-native/feral status, population size, body mass, biomass) and conflicts for each species is in S2 Table. The periods during which conflicts were reported in the scientific literature (i.e. identified during the original review only ("pre-2014"), during the original and current review ("pre-2014 and 2014 to present") and during the current review only ("2014 to present") are also shown. The median impact scores and confidence ratings are shown after each conflict in parentheses.

Overview of conflicts

Conflicts and status

Twenty-nine of the 48 mammals (61%) are native to the British Isles, 17 (35%) are non-native (which includes 10 that have been introduced in recent times and seven that are considered naturalised) and two (4%) are feral (species that are considered wild but are either managed or may have human dependence). Of the 48 mammals, 40 (83%) caused at least one economic conflict, 36 (75%) caused at least one health conflict, 23 (48%) caused at least one environmental conflict and eight (17%) caused at least one social conflict (Fig 1). When compared by status, 86% (25/29) of native mammals caused economic conflict, 66% (19/29) caused health conflict and 35%

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294 (10/29) caused environmental conflict. In comparison, 82% (14/17) of non-native
295 mammals caused economic conflict, 88% (15/17) caused health conflict and 71%
296 (12/17) caused environmental conflict. Social conflicts accounted for approximately
297 17% for both native (5/29) and non-native (3/17) species. The proportion of feral
298 mammals causing conflict was either 50% (economic and environment) or 100%
299 (health), although this was attributable to only two species (feral cat, Dartmoor/Exmoor
300 pony).

301 **Fig 1. Percentage of mammals within each status causing conflict within the**
302 **four main categories. Data labels denote the number of mammals within each**
303 **status.**

304 Frequency of conflicts

305 In total, 200 separate conflicts were identified, with 103 attributable to native mammals
306 (52%), 92 to non-native mammals (46%) and five to feral mammals (3%). Ninety-one
307 of the 200 conflicts (45%) were economic impacts (Appendix 1a), 71 (35%) were
308 health impacts (Appendix 1b), 29 (15%) were environmental impacts (Appendix 1c)
309 and nine (5%) were social impacts (Appendix 1d). A similar proportion of conflicts were
310 recorded for both native and non-native species within all four categories (Fig 2). For
311 native mammals, economic impacts accounted for 47% (48/103), health impacts
312 accounted for 36% (37/103), environmental impacts accounted for 11% (12/103) and
313 social impacts accounted for 6% (6/103). For non-native mammals, economic impacts
314 accounted for 45% (42/92), health impacts accounted for 36% (32/92), environmental
315 impacts accounted for 16% (15/92) and social impacts accounted for 3% (3/92). Feral
316 mammals were involved in considerably less conflicts, mostly attributable to health
317 and environmental impacts.

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Fig 2. The percentage of conflicts within each category depending on status. Data labels denote the number of conflicts within each category. Native mammals: n=103; non-native mammals: n=92; feral mammals: n=5.

The total number of mammals causing conflict within a particular subcategory ranged from one to 30 (Appendix 1a-1d). Two of the four most common conflicts were health related (reservoir of zoonotic disease, n=30; reservoir of disease, n=22) followed by two economic conflicts (damage to agricultural interests, n=19; damage to forestry, n=15), with a similar number of native and non-native mammals causing conflict in these subcategories. However, when these data were analysed separately according to status, non-native mammals accounted proportionately more than native mammals in all four subcategories (Fig 3).

Fig 3. The percentage of native and non-native mammals causing conflict within the four most common conflict subcategories. Data labels denote the number of mammals. Native: n=29; non-native: n=17.

Impact scores and ranking of conflicts

Reproducibility of the scoring

Of the 200 conflicts, the three reviewers agreed on the impact score in 92 cases (46%); there was a maximum deviation of one score in 89 cases (44%), a maximum deviation of two scores in 18 cases (9%) and a maximum deviation of three scores in 1 case (1%). Overall, there was no statistically significant difference between the independently assigned impact scores ($\chi^2(2)=3.057$, $p=0.217$). However, confidence scores were found to differ statistically between reviewers ($\chi^2(2)=144.54$, $p<0.001$); all three agreed in 33 of the 200 conflicts (17%), two agreed in 131 cases (65%), with a

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deviation of one or two assigned by the third reviewer, and all three assigned a different confidence score in 36 cases (18%). This suggests that the reviewers were largely consistent in their impact scoring of British mammals but not necessarily in the confidence of the assignments.

Conflict scoring and ranking

Using the median impact scores across the three reviewers, seven of the 200 conflicts (4%) were assessed as impact score 5, 20 (10%) as impact score 4, 30 (15%) as impact score 3, 88 (44%) as impact score 2 and 55 (27%) as impact score 1 (Table 4a-4d). Six of the seven conflicts assessed as having the highest impact score of 5 (all with confidence rating of high) were economic and one was a health conflict. These were (in order of highest approximate economic cost): (1) rabbit damage to agricultural interests (£120 million), (2) badger involvement in the transmission of bTB to cattle (>£100 million), (3) brown rat damage to agricultural interests (£54 million), (4) rabbit damage to forestry (£43 million) (5) badger damage to agricultural interests (£39 million) (6) grey squirrel damage to forestry (£28 million, not including carbon capture estimates) and (7) brown rat damage to property (£14 million, based on local authority costs only). In all four categories, the majority of conflicts were scored as impact 2 (economic: 35% (32/91); health: 46% (33/71); environmental: 55% (16/29); social: 78% (7/9)). Despite two health conflicts being the most common amongst all mammals, generally, health conflicts were scored low, with over 90% (64/71) scoring either a 1 or 2.

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Table 4a. Total number of mammals causing conflict within the 15 economic subcategories and their median impact score. Status categories: Na=native; NN=non-native; Fe=feral.

	Mammal impact scores within each subcategory					Total per status
Conflict (total mammals)	**Impact 5**	**Impact 4**	**Impact 3**	**Impact 2**	**Impact 1**	
Damage to forestry (15)	Grey squirrel, rabbit	Roe deer, red deer, fallow deer	Japanese sika, brown hare, edible dormouse, field vole	Muntjac, feral goat, mountain hare, beaver, bank vole	Chinese water deer	**Na - 6** **NN - 9**
Damage to agricultural interests (19)	Badger, rabbit, brown rat	Roe deer, fallow deer, mole, house mouse	Red deer	Japanese sika, Chinese water deer, muntjac, wild boar, brown hare, mountain hare, grey squirrel, beaver, wood mouse	Edible dormouse, field vole	**Na - 9** **NN - 10**
Damage to vehicles (RTAs) (9)	-	Roe deer, fallow deer, badger	Red deer, muntjac	Japanese sika, Chinese water deer, wild boar, Exmoor/Dartmoor pony	-	**Na - 4** **NN - 4** **Fe - 1**
Competition with livestock (3)	-	-	-	-	Red deer, Japanese sika, feral goat	**Na - 1** **NN - 2**
Predation of game species (11)	-	Red fox	-	Stoat, badger, American mink, hedgehog, brown rat	Wild cat, pine marten, feral ferret, weasel, polecat	**Na - 8** **NN - 3**
Predation/impact on commercial fisheries (3)	-	-	-	Otter, American mink	Beaver	**Na - 2** **NN - 1**
Predation of poultry (4)	-	-	-	American mink	Pine marten, feral ferret, polecat	**Na - 2** **NN - 2**
Damage to property (6)	Brown rat	Badger, grey squirrel, house mouse	Edible dormouse	Natterer's bat	-	**Na - 2** **NN - 4**
Damage to amenities and domestic grassland (4)	-	Rabbit	American mink, mole	Badger	-	**Na - 2** **NN=2**
Conflicts with construction, infrastructure and development (9)	-	Badger	Natterer's, serotine, common pipistrelle, soprano pipistrelle, brown long-eared bat	Beaver, hazel dormouse, water vole	-	**Na - 9**
Predation of livestock (1)	-	Red fox	-	-	-	**Na - 1**
Conflicts with transport (2)	-	-	Rabbit, brown rat	-	-	**NN - 2**
Sustaining predators harmful to game (2)	-	-	-	-	Field vole, Orkney vole	**Na - 1** **NN - 1**

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Damage to property as a result of poaching (2)				Brown hare	Mountain hare	**Na - 1** **NN - 1**
Conflicts with utilities (1)	-	Brown rat	-	-	-	**NN - 1**
Total per impact score	**6**	**18**	**17**	**32**	**18**	**91**

Table 4b. Total number of mammals causing conflict within the six health subcategories and their median impact score. Status categories: Na=native; NN=non-native; F=feral.

	Mammal impact scores within each subcategory					**Total per status**
Conflict (total mammals)	**Impact 5**	**Impact 4**	**Impact 3**	**Impact 2**	**Impact 1**	
Health risks from RTAs (9)	-	-	Roe deer, wild boar	Red deer, Japanese sika, fallow deer, muntjac, badger	Chinese water deer, Exmoor/Dartmoor pony	**Na - 4** **NN - 4** **Fe - 1**
Reservoir of disease (22)	-	-	Rabbit, grey squirrel	Roe deer, red deer, fallow deer, muntjac, wild boar, feral cat, badger, red fox, field vole, wood mouse, house mouse	Japanese sika, Chinese water deer, feral goat, stoat, Daubenton's, hedgehog, brown hare, red squirrel, beaver	**Na - 12** **NN - 9** **Fe - 1**
bTB transmission (8)	Badger	-	-	Fallow deer, muntjac, wild boar	Roe deer, red deer, Japanese sika, red fox	**Na - 5** **NN - 3**
Reservoir of zoonotic disease (30)	-	Brown rat	House mouse	Roe deer, red deer, fallow deer, muntjac, American mink, red fox, Daubenton's, serotine, hedgehog, rabbit, bank vole, field vole, wood mouse	Japanese sika, Chinese water deer, feral goat, polecat, common shrew, greater white-toothed shrew, brown hare, mountain hare, red squirrel, grey squirrel, beaver, edible dormouse, yellow-necked mouse, Skomer vole, black rat	**Na - 15** **NN - 15**
Threat to livestock where ground is undermined (1)	-	-	-	Mole	-	**Na - 1**
Threats of branches falling (1)	-	-	-	-	Grey squirrel	**NN - 1**
Total per impact score	**1**	**1**	**5**	**33**	**31**	**71**

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Table 4c. Total number of mammals causing conflict within the seven environmental subcategories and their median impact score. Status categories: Na=native; NN=non-native; F=feral.

	Mammal impact scores within each subcategory					Total per status
Conflict (total mammals)	**Impact 5**	**Impact 4**	**Impact 3**	**Impact 2**	**Impact 1**	
Damage to conservation habitats (9)	-	-	Roe dee, red deer	Japanese sika, fallow deer, muntjac, feral goat	Chinese water deer, wild boar, bank vole	**Na - 4** **NN - 5**
Threat to biodiversity (6)	-	Grey squirrel	-	Roe deer, red deer, Japanese sika, fallow deer, greater white-toothed shrew	-	**Na - 2** **NN - 4**
Threat to genetic integrity (3)	-	-	Feral cat	Japanese sika, feral ferret	-	**NN - 2** **Fe - 1**
Competition with or predation of wildlife (including protected or conservation species) (7)	-	-	Badger, American mink, red fox	Feral cat, otter, pine marten, stoat	-	**Na - 5** **NN - 1** **Fe - 1**
Predation of important ground-nesting birds and island ecosystem damage (2)	-	-	Hedgehog, brown rat	-	-	**Na - 1** **NN - 1**
Sustaining predators harmful to important conservation species (1)				Rabbit	-	**NN - 1**
Damage to island ecosystems (1)	-	-	-	-	Black rat	**NN - 1**
Total per impact score	**0**	**1**	**8**	**16**	**4**	**29**

Table 4d. Total number of mammals causing conflict within the four social subcategories and their median impact score. Status categories: Na=native; NN=non-native; F=feral.

	Mammal impact scores within each subcategory					Total per status
Conflict (total mammals)	**Impact 5**	**Impact 4**	**Impact 3**	**Impact 2**	**Impact 1**	
Public nuisance (4)	-	-	-	Muntjac, feral goat, rabbit	Wild boar	**Na - 1** **NN - 3**
Domestic nuisance (2)	-	-	-	Pine marten	Red fox	**Na - 2**
Predation of domestic pets (1)	-	-	-	Red fox	-	**Na - 1**
Domestic nuisance & hygiene (2)	-	-	-	Natterer's, serotine	-	**Na - 2**
Total per impact score	**0**	**0**	**0**	**7**	**2**	**9**

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Analysis of impact scores in relation to native/non-native status and conflict category, found a statistically significant effect of category, when considered as a main order effect ($\chi^2(3)=62.90$, $p<0.001$) but not status ($\chi^2(1)=0.421$, $p=0.516$). Reviewers assigned a greater score in relation to economic impacts, followed by environmental, health and then social impacts (Fig 4). When conflict category was considered in relation to status, there was no statistically significant interaction term between the two ($\chi^2(3)=4.839$, $p=0.184$)

Fig 4. The proportion of conflicts depending on impact score (1-5) within the four categories. Data labels denote to total number of conflicts within each impact score. Economic: n=91, health: n=71, health: n=29, social: n=9.

Analysis of impact scores, in relation to native/non-native status and conflict subcategories, showed both as having a statistically significant effect ($\chi^2(1)=33.63$, $p<0.001$; $\chi^2(31)=640.18$, $p<0.001$, respectively), with a significant two-way interaction term also identified ($\chi^2(31)=155.56$, $p<0.001$). Across all economic impacts, non-native species received a statistically significantly greater impact score than natives in relation to damage to woodland, damage to agricultural interests, damage to property, conflict with transport and conflict with utilities (all $p<0.05$). Conversely, native species received a significantly higher score due to conflicts with construction and development and the predation of livestock (both $p<0.001$). Across health impacts, the model predicted a statistically greater impact score for non-native species as reservoirs of zoonotic diseases only ($p=0.008$). With regards to the environment, non-native species received a statistically significant greater impact score for damage to conservation habitats and their threat to biodiversity and genetic integrity (all $p<0.05$).

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In terms of social impacts, non-native species received a greater impact than natives with respect to public nuisance only ($p<0.01$).

Potential impact

The number of separate conflicts per species ranged from one to eleven (Table 5), with sika deer involved in the most conflicts. Species scoring highest in potential total impact (i.e. the sum of all median conflict scores for a particular species) were badger, rabbit, roe deer, fallow deer and red deer. Generally, these species also scored highly within the separate categories (except for social conflicts), with badgers scoring highest in both potential economic and health impacts. The highest potential environmental impact was produced by sika deer, followed by roe deer, red deer and feral cat. The highest potential social impact was observed in the red fox, followed by rabbit, wild boar, pine marten, Natterer's and serotine bat.

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Table 5. Distribution (i.e. the proportion of Great Britain each mammal is found, based on presence in 10x10km squares), total number of conflicts and impact scores (potential and actual) in total and within each of the four categories (economic, health, environmental, social) for all conflict mammals. Mammals are listed in order of highest total actual impact. – denotes missing data.

Species	Distribution	No. conflicts	Potential impact					Actual impact				
			Total potential impact	Economic	Health	Environment	Social	Total actual impact	Economic	Health	Environment	Social
Badger	0.746	10	33	21	9	3	0	24.624	15.670	6.716	2.239	0
Rabbit	0.833	8	26	17	5	2	2	21.649	14.155	4.163	1.665	1.665
Roe deer	0.726	9	25	12	8	5	0	18.151	8.713	5.808	3.630	0
Red fox	0.800	8	19	8	5	3	3	15.207	6.403	4.002	2.401	2.401
Grey squirrel	0.583	7	20	11	5	4	0	11.653	6.409	2.913	2.331	0
Brown rat	0.529	7	21	14	4	3	0	11.105	7.403	2.115	1.586	0
Red deer	0.412	10	23	11	7	5	0	9.480	4.534	2.885	2.061	0
Fallow deer	0.347	9	24	12	8	4	0	8.317	4.158	2.772	1.386	0
American mink	0.533	6	14	9	2	3	0	7.457	4.794	1.065	1.598	0
Mole	0.807	3	9	7	2	0	0	7.266	5.651	1.615	0	0
Hedgehog	0.824	4	8	2	3	3	0	6.592	1.648	2.472	2.472	0
Brown hare	0.680	5	9	7	2	0	0	6.119	4.759	1.360	0	0
Muntjac	0.334	9	17	7	8	2	0	5.673	2.336	2.669	0.667	0
Field vole	0.564	5	9	5	4	0	0	5.075	2.819	2.256	0	0
Wood mouse	0.560	3	6	2	4	0	0	3.360	1.120	2.240	0	0
Otter	0.782	2	4	2	0	2	0	3.126	1.563	0	1.563	0
House mouse	0.235	4	13	8	5	0	0	3.060	1.883	1.177	0	0
Stoat	0.597	3	5	2	1	2	0	2.983	1.193	0.597	1.193	0
Natterer's	0.411	3	7	5	0	0	2	2.880	2.057	0	0	0.823
Sika deer	0.134	11	19	8	5	6	0	2.540	1.069	0.668	0.802	0
Bank vole	0.446	3	5	2	2	1	0	2.229	0.892	0.892	0.446	0
Common pipistrelle	0.674	1	3	3	0	0	0	2.021	2.021	0	0	0
Soprano pipistrelle	0.619	1	3	3	0	0	0	1.858	1.858	0	0	0
Brown long-eared bat	0.600	1	3	3	0	0	0	1.799	1.799	0	0	0
Serotine	0.246	3	7	3	2	0	2	1.721	0.738	0.492	0	0.492
Daubenton's	0.491	2	3	0	3	0	0	1.472	0	1.472	0	0
Pine marten	0.171	4	6	2	0	2	2	1.025	0.342	0	0.342	0.342

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Table 5 cont.

			Potential impact					Actual impact				
Species	**Distribution**	**No. conflicts**	**Total potential impact**	**Economic**	**Health**	**Environment**	**Social**	**Total actual impact**	**Economic**	**Health**	**Environment**	**Social**
Mountain hare	0.162	4	6	5	1	0	0	0.973	0.811	0.162	0	0
Water vole	0.425	1	2	2	0	0	0	0.850	0.850	0	0	0
Polecat	0.269	3	3	2	1	0	0	0.807	0.538	0.269	0	0
Weasel	0.530	1	1	1	0	0	0	0.530	0.530	0	0	0
Common shrew	0.502	1	1	0	1	0	0	0.502	0	0.502	0	0
Red squirrel	0.247	2	2	0	2	0	0	0.494	0	0.494	0	0
Feral goat	0.023	6	13	4	7	1	1	0.209	0.070	0.047	0.047	0.047
Hazel dormouse	0.199	1	2	2	0	0	0	0.397	0.397	0	0	0
Chinese water deer	0.042	7	9	5	3	1	0	0.375	0.208	0.125	0.042	0
Wild boar	0.031	7	9	3	2	2	2	0.402	0.124	0.216	0.03	0.031
Beaver	0.018	6	9	7	2	0	0	0.166	0.129	0.037	0	0
Yellow-necked mouse	0.129	1	1	0	1	0	0	0.129	0	0.129	0	0
Edible dormouse	0.008	4	8	7	1	0	0	0.064	0.056	0.008	0	0
Wildcat	0.039	1	1	1	0	0	0	0.039	0.039	0	0	0
Exmoor/Dartmoor pony	0.005	2	3	2	1	0	0	0.016	0.011	0.005	0	0
Black rat	0.006	2	2	0	1	1	0	0.011	0	0.006	0.006	0
Skomer vole	0.004	1	1	0	1	0	0	0.004	0	0.004	0	0
Orkney vole	0.003	1	1	1	0	0	0	0.003	0.003	0	0	0
Feral cat	-	3	7	0	2	5	0	-	-	-	-	-
Feral ferret	-	3	4	2	0	2	0	-	-	-	-	-
Greater white-toothed shrew	-	2	3	0	1	2	0	-	-	-	-	-

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Analyses identified a statistically significant difference between native/non-native species ($\chi^2(1)=4.235$, $p=0.040$), with the latter predicted as having a higher potential impact overall ($\beta=0.513$, z ratio=2.058, $p=0.046$). When specified as main order effects, total potential impact was found to increase as a function of body mass ($\beta=0.335$, t ratio=3.598, $p<0.001$) and biomass ($\beta=0.184$, t ratio=4.706, $p<0.001$) but not population size ($\beta=0.040$, t ratio=1.012, $p=0.311$). However, no statistically significant interaction term was identified ($p>0.05$), suggesting that differences in the rate of change for total potential impact were comparable between native and non-native species, relative to changes in population size, body mass and biomass.

There was a statistically significant difference between taxonomic orders ($\chi^2(5)=18.468$, $p=0.002$), with Artiodactyla having a higher potential impact compared to Chiroptera ($\beta=1.129$, t ratio=3.661, $p=0.009$) and Rodentia ($\beta=1.231$, t ratio=3.236, $p=0.028$), whilst all other taxonomic comparisons were non-significant (Fig 5). Inclusion of covariate predictors as main order effects, revealed a statistically significant effect of population size ($\chi^2(1)=7.259$, $p=0.007$) and biomass ($\chi^2(1)=39.467$, $p<0.001$), with total potential impact predicted to increase as a function of each (population size: $\beta=0.096$, t ratio=2.499, $p<0.001$; biomass: $\beta=0.199$, t ratio=5.641, $p<0.001$).

Figure 5. Average potential impacts within the four categories across orders (excluding Perissodactyla).

Actual impact

Species scoring the highest actual impact were badger, rabbit, roe deer and red fox (Table 5). Generally, these species also scored highly within the separate categories, with badgers scoring highest in both actual economic and health impacts. Roe deer

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scored the highest actual environmental impact, followed by hedgehog, red fox, grey squirrel, badger and red deer. The highest potential social impact was observed in the red fox, followed by rabbit and Natterer's bat.

Analysis of actual impact estimates showed no statistically significant difference between native/non-native species ($\chi^2(1)=0.056$, $p=0.813$). When considered as main order effects, total actual impact was predicted to increase significantly in relation to population size ($\beta=0.094$ t ratio=1.980, $p=0.048$) and biomass ($\beta=0.215$, t ratio=4.691, $p<0.001$). When considered in relation to status, there was no statistically significant interaction for biomass ($\chi^2(1)=0.298$, $p=0.585$) suggesting that the rate of increase was comparable across native and non-native species. Body mass was found to have no statistically significant effect on total actual impact when considered as a main order effect ($\chi^2(1)=1.741$, $p=0.187$) or through interaction with status ($\chi^2(1)=0.088$, $p=0.767$). A statistically significant interaction term was identified between status and population size, with total actual impact predicted to increase, relative to population size, at a significantly higher rate for non-native species when compared to natives ($\beta=0.179$, t ratio=2.120, $p=0.034$).

There was no statistical difference, in relation to actual impact scores, between the taxonomic orders ($\chi^2(5)=5.622$, $p=0.345$: Fig 6).

Figure 6. Average actual impacts within the four categories across orders (excluding Perissodactyla).

Conflict change over time

For many mammals, a conflict occurring before 2014 was still being reported in the scientific literature within the last decade (S2 Table). Twenty-seven of the 46 (59%)

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466 conflicts reported only before 2014 were economic, followed by 10 (22%) health, 5
467 environment (11%) and 4 social (8%). In contrast, 25 of the 45 (55%) conflicts reported
468 from 2014 to 2024 were health (55%), mostly attributable to reservoir of disease or
469 reservoir of zoonotic disease, followed by 9 environment (20%), 8 economic (18%)
470 and 3 social (7%).

471 Discussion

472 Negative interactions between people and wildlife are more often than not viewed as
473 human–wildlife conflict, with socio-economic factors cited amongst the issues
474 influencing people's perception of wildlife [45]. In this paper, we estimated a
475 conservative total annual economic cost of human-wildlife conflicts in Great Britain (as
476 reported in S1 File) in excess of £0.5 billion, which would likely exceed £1 billion if
477 health and environmental conflicts could be monetarised. All but one of the seven
478 conflicts assessed as having the highest impact score of 5 involved economic conflicts.
479 The one health conflict scored as impact 5 (the involvement of badgers in the
480 transmission of bTB), was also measurable on an economic scale, suggesting that
481 conflicts associated with a monetary value are inherently easier to quantify compared
482 with those that are not. To account for potential bias associated with individual
483 conflicts, we applied a prioritisation approach (generic impact scoring system (GISS))
484 to evaluate the overall impact of conflict mammals. In some cases, mammals causing
485 the greatest economic damage, such as rabbit and badger, were ranked highest
486 overall for their actual impact. However, this approach also identified species that did
487 not necessarily cause the highest individual impacts; for example, roe deer and red
488 fox were ranked third and fourth overall, respectively, for actual impact despite neither
489 receiving the highest impact score of 5 for any of their identified conflicts.

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The emphasis of legislation associated with wildlife in the UK has moved from protecting human economic interests (e.g. Prevention of Damage by Pests Act 1949 and Pests Act 1954), to promoting animal welfare (e.g. Wildlife and Countryside Act 1981 and Animal Welfare Act 2006) and protecting biodiversity (e.g. Habitats Directive 1992, Environment Act 2021). There is likely to be an increasing trend for conflicts arising between promoting biodiversity and human economic interests, as human activities continue to expand into existing wildlife habitats. Four of the five mammals identified as causing the greatest actual economic and health impact (badger, rabbit, roe deer), environmental impact (roe deer, hedgehog, red fox), and social impact (red fox, rabbit) are native, which leads to increasing conflict where specific legislation applies to a protected species. For example, badgers are protected under the Protection of Badgers Act 1992 but are the focus of ongoing controversy regarding management options for controlling the spread of *Mycobacterium bovis* to cattle in the UK, which is estimated to cost the taxpayer over £100 million annually [46]. Likewise, some bat species are widely distributed throughout Great Britain and often associated with conflicts with buildings or construction; as bats and their roosts are legally protected under the Wildlife and Countryside Act 1981 and the Conservation of Habitats and Species Regulations 2010, this can lead to potentially complex and costly resolution.

Although native mammals were ranked amongst the highest scoring impacts in all four categories, overall, there was no statistical difference in the impact scores between native and non-native species. However, there was a disproportionate amount of conflict in specific areas, with non-native species perceived as causing significantly more damage to woodlands, conservation habitats and agricultural interests, and a greater reservoir of zoonotic disease compared to native species.

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515 Rabbits caused the highest economic conflict compared to all other mammals with
516 their impact on agriculture, and ranked second overall for total actual impact. As such,
517 this may highlight rabbits as a priority species for human-wildlife resolution. However,
518 rabbit populations have declined significantly in the UK in recent years, with severe
519 local population reductions reported [47], which have led to concerns regarding the
520 impact of such population reductions on other species, such as carnivores, that rely
521 on them as a food source [48]. In contrast, grey squirrel abundance and distribution
522 has expanded rapidly since they were introduced to Great Britain in the late 19th
523 century [49]. They are considered a pest species in the UK and as such are afforded
524 no protection under the Wildlife and Countryside Act 1981. As part of its 25-year
525 Environment plan [20], the government has committed to managing grey squirrels to
526 protect woodlands and red squirrel populations in the UK. While the general
527 consensus is that grey squirrels must be managed to protect biodiversity within the
528 UK, removing healthy wildlife can be controversial and may face opposition from
529 pressure groups, which can be key to the success or failure of an eradication project
530 [50].

531 Although the majority of reported conflicts were economic, the two most common
532 conflicts were health related (reservoir of zoonotic disease and reservoir of disease).
533 More than 60% of human pathogens are zoonotic in origin [51] with urbanisation and
534 anthropogenic factors, amongst others, thought to have greatly influenced the
535 emergence and distribution of zoonoses [52]. Generally, though, the impact score of
536 health conflicts were deemed low (mostly 1 or 2), therefore we assumed that most
537 health impacts were likely local, mild, short- to mid-term and with reversible effects
538 (see Table 1). This highlights the importance of surveillance, which is crucial to
539 preventing and controlling the spread of disease, in particular zoonotic disease [52].

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This is also pertinent to exotic diseases, which are not reported here as only current diseases causing conflict in Britian were assessed. Whilst there is extensive research on the pathology and epidemiology of disease in a wide range of British mammals, as reported in S1 File, it is evident that for some mammals, there is an inference of disease presence and/or zoonotic potential or a general lack of information (e.g. some hantaviruses [53] and Ljungan virus [54] in rodents; *Babesia* spp. in deer [55] and badgers [56]), which suggests further research may be warranted. Understanding disease dynamics in British wildlife is intrinsically linked to biodiversity conservation, as anthropogenic activities such as urbanisation and habitat destruction, are likely to lead to increased interaction between humans and wildlife [57].

In many cases, mammals that caused the most conflict were amongst the most widely distributed throughout the British Isles, e.g. badger, rabbit, roe deer and red fox. Our analyses identified that total actual impact tended to increase as a function of biomass and population size, therefore a GISS approach may be particularly beneficial for monitoring recently introduced species, whether native or non-native, which have the potential to expand beyond their current range. Beavers were reintroduced to Great Britain around 20 years ago and are considered keystone species due to their ability to alter ecosystem structure and function through their engineering activities [58, 59]. Whilst beavers are generally considered as having a positive impact on biodiversity, we identified six potential conflicts of interest with humans; whilst they ranked 38th overall based on total actual impact, likely owing to their current limited distribution, they ranked joint 12th overall based on potential impact. Whilst the reintroduction of beavers across Great Britain is currently carefully managed, highlighting and monitoring potential issues at this stage is essential for ensuring the

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status of this species remains positive rather than possible future perception as a pest species.

The overall assessments of the conflicts reported here were made at the national level for Great Britain. Local impacts may be of considerable importance for those affected, for instance those injured in road traffic accidents, and thus a national score of 1 or 2 should not be taken to indicate that the conflict is not important or worth mitigating at a local level. Furthermore, it is important to recognise that the impacts are not necessarily uniformly distributed geographically or equitably shared. For example, Artiodactyla were predicted to receive significantly higher potential impact scores compared to other taxonomic orders. The total potential impact for five of the six deer species were amongst the highest of all the mammals, although the actual impact for some deer species may be lower depending on their distribution. For example, sika deer were involved in the most conflicts of all the mammals but were ranked 20th overall for actual impact, suggesting its impacts are localised given its limited distribution.

Human-wildlife conflict has long been associated with negative impacts on human interests, although it is evident that interactions between people and wildlife are more varied and complex [2]. More recently, the emphasis has shifted from conflict between humans and wildlife and its mitigation, to a coexistence approach [14], or at least one that constrains conflict or adapts shared spaces to mitigate conflict. Whilst there is a general consensus that some species must be managed or even eradicated (e.g. invasive non-native species: Nentwig et al. [15]), for others, particularly native species, a more holistic approach may be required. In some cases, mammals that represent a conflict and cost to some, may also provide a benefit to others. In Great Britain, the red fox has been widely persecuted due to its perceived status as a pest species [60].

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589 Their impact on agriculture has been estimated to cost £20 million annually, most of
590 which is attributable to direct and indirect effects of livestock predation [61]. However,
591 fox predation on rabbits, which have a much more significant impact on agriculture, is
592 estimated to create an indirect economic benefit to farmers of at least £11 million
593 annually and may even be approaching an economically neutral impact on agriculture
594 [61].

595 The findings reported here must be viewed in light of several limitations. Although
596 an extensive literature search was conducted to identify conflicts associated with
597 British wildlife, it is likely that some conflicts were not identified or cost estimates were
598 not available, and therefore not reported. Whilst the conflict descriptions given in S1
599 File are not exhaustive and based only on the searches returned, they likely represent
600 reasonable overviews and are sufficiently robust to provide an overall audit of the
601 current national importance of conflicts between human and wildlife interests in Great
602 Britain. However, individual assignments of scale may need to be revised as further
603 information emerges. Conflicts that were identified before 2014 only are more than
604 likely still occurring or may not be reported as frequently in the scientific literature.
605 Likewise, conflicts reported after 2014 only may have been occurring prior to this and
606 again, either missed in the original literature searches or less frequently reported. The
607 majority of “new” conflicts we identified were disease related, which may reflect a shift
608 of focus leading to increased reporting in this area, possibly in light of several
609 international public health emergencies of zoonotic origin within the last ten years,
610 such as Middle East respiratory syndrome (MERS), Ebola and Covid-19 pandemics
611 [62].

612 Another limitation of our findings is the lack of data for some species. Feral species
613 were excluded from some of the analyses due to the small number of conflicts in Great

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Britain, although their impacts can be significant. Data regarding feral cats are limited due to the difficulty in differentiating between feral and domestic cats [63], the uncertainties of feral cat population estimates (based mostly on urban populations) and the lack of known distribution within Great Britain. Cats are one of the most ubiquitous mammals globally (see McDonald & Skillings [64]) and one of the most destructive, with free-ranging cats suggested as having a major impact on the mortality of several bird species in the UK [65]. They are also the biggest threat to the survival of Scottish wildcats due to introgression [66]. Given their domesticated origins, feral cats have no native range and their ubiquitous adverse impacts on native wildlife around the world has led to them being labelled amongst the world's worst invasive species [67]. From a biodiversity conservation perspective, a wealth of evidence suggests that feral cats should be controlled and ideally removed from places where their impact is detrimental, often as an urgent priority [68].

When applying the GISS in this paper, none of the conflicts were weighted, i.e. they were all considered of equal importance. This follows Nentwig et al. [15], who stated that in the absence of objective scientific criteria to consider one impact category more important than the other, selective weights were not applied. They also stated that deciding relative impact weights is a social process rather than a scientific one. It is possible to apply individual weights to conflicts, for example, by considering stakeholder values (e.g. Kumschick et al. [69]), which will likely differ according to the relevance of a particular conflict to a particular group. The scoring system applied here is thus considered robust to the uncertainty of impact knowledge but could be adjusted with weight scores to account for specific social values, such as stakeholder interests, in the future [15].

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Conclusions

The prioritisation approach we applied here is a useful tool for identifying individual conflicts for individual species but also provides a broader assessment of where human-wildlife impacts may be affecting socio-economic and biodiversity interests. It is clear that it should not be relied upon in isolation to identify priority species for mitigation purposes, and all other available evidence or opinion from conservation groups, stakeholder groups, public perception and other interested parties, should be considered. Ideally, any decision making, whether relevant to government policies or conservation organisations, should consider ensuring a balance between the need to conserve and enhance biodiversity, the interests of the general public and the interests of those directly affected [35].

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Author contributions

Conceptualisation and methodology: DC, KLP. Analysed the data: KP, DW, DC, GC. Writing-original draft: KP. Writing-review & editing: KP, DC, DW, GC.

References

1. Locke H, Ellis EC, Venter O, Schuster R, Ma K, Shen X, et al. Three global conditions for biodiversity conservation and sustainable use: an implementation framework. National Science Review. 2019;6:1080-82.

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658 2. Hill CM. Conflict is integral to human-wildlife coexistence. Frontiers in
659 Conservation Science. 2021;2:734314.
660 3. Woodroffe R, Thirgood S, Rabinowitz A. People and wildlife: conflict or
661 coexistence? Cambridge, UK: Cambridge University Press; 2005.
662 4. Conover MR. Resolving human-wildlife conflicts: the science of wildlife damage
663 management: CRC Press, Boca Raton, FL; 2002.
664 5. Treves A, Karanth KU. Human-carnivore conflict and perspectives on carnivore
665 management worldwide. Conservation Biology. 2003;17:1491–99.
666 6. Tilman D. Global environmental impacts of agricultural expansion: the need for
667 sustainable and efficient practices. The Proceedings of the National Academy of
668 Sciences. 1999;96:5995–6000.
669 7. Nyhus PJ. Human-wildlife conflict and co-existence. Annual Review of
670 Environment and Resources. 2016;41:143-71.
671 8. Pérez E, Pacheco LF. Damage by large mammals to subsistence crops within
672 a protected area in a montane forest of Bolivia. Crop Protection. 2006;25:933-39.
673 9. Fang L, Hong Y, Zhou Z, Chen W. The frequency and severity of crop damage
674 by wildlife in rural Beijing, China. Forest Policy and Economics. 2021;124:102379.
675 10. Drexler JF, Corman VM, Drosten C. Ecology, evolution and classification of bat
676 coronaviruses in the aftermath of SARS. Antiviral Research. 2014;101:45-56.
677 11. Song Z, Xu Y, Bao L, Zhang L, Yu P, Qu Y, et al. From SARS to MERS,
678 thrusting coronaviruses into the spotlight. Viruses. 2019;11.
679 12. Hao YJ, Wang YL, Wang MY, Zhou L, Shi JY, Cao JM, et al. The origins of
680 COVID-19 pandemic: A brief overview. Transboundary and Emerging Diseases.
681 2022;69(6):3181-197.

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682 13. Cassini MH. Human-wildlife conflicts: does origin matter? . Animals. 2022;12:1-
683 10.
684 14. Gross EM, Jayasinghe N, Dahal S, Tenzin S, Klenzendorf S, Vannelli K, et al.
685 C2C—conflict to coexistence: a global approach to manage human–wildlife conflict for
686 coexistence. Conservation Science and Practice. 2024;7:e13292.
687 15. Nentwig W, Künel E, Bacher S. A generic impact-scoring system applied to
688 alien mammals in Europe. Conservation Biology. 2010;24:302–11.
689 16. Eschen R, Kadzamira M, Stutz S, Ogunmodede A, Djeddour D, Shaw R, et al.
690 An updated assessment of the direct costs of invasive non native species to the United
691 Kingdom. Biological Invasions. 2023;25:3265-76.
692 17. The Wildlife Trust. Local to global: the Global Biodiversity Framework and what
693 the UK needs to do to implement it. 2024;
694 https://www.wildlifetrusts.org/sites/default/files/2024-
695 09/UK%20and%20Global%20Biodiversity%20Framework%20-
696 %20The%20Wildlife%20Trusts%202024.pdf.
697 18. Dueñas MA, Hemming DJ, Roberts A, Diaz-Soltero H. The threat of invasive
698 species to IUCN-listed critically endangered species: a systematic review. Global
699 Ecology and Conservation. 2021;26:e01476.
700 19. NNSS. GB non-native species report card 2020. 2020;
701 https://www.nonnativespecies.org/assets/NNSIP-Scorecard-2020.pdf.
702 20. HMGovernment. A green future: our 25 year plan to improve the environment.
703 2018;
704 https://assets.publishing.service.gov.uk/media/65fd713d65ca2f00117da89e/CD1.H_
705 HM_Government_A_Green_Future_Our_25_Year_Plan_to_Improve_the_Environme
706 nt.pdf; 2018.

21. Crowley SL, Hinchliffe S, McDonald RA. Conflict in invasive species management. Frontiers in Ecology and the Environment. 2017;15:133-41.

22. Jackson DB, Green RE. The importance of the introduced hedgehog (*Erinaceus europaeus*) as a predator of the eggs of waders (Charadrii) on machair in South Uist, Scotland. Biological Conservation. 2000;93:333–48.

23. Manchester SJ, Bullock JM. The impacts of non-native species on UK biodiversity and the effectiveness of control. Journal of Applied Ecology. 2000;37:845-64.

24. Ricciardi A, Cohen J. The invasiveness of an introduced species does not predict its impact. Biological Invasions. 2007;9:309–15.

25. Ricciardi A, Hoopes MF, Marchetti MP, Lockwood JL. Progress toward understanding the ecological impacts of nonnative species. Ecological Monographs,. 2013;83:263–82.

26. Swift BMC, Barron ES, Christley R, Corbetta D, Grau-Roma L, Jewell C, et al. Tuberculosis in badgers where the bovine tuberculosis epidemic is expanding in cattle in England. Scientific Reports. 2021;11:20995.

27. Kumschick S, Gaertner M, Vilà M, Essl F, Jeschke JM, Pyšek P, et al. Ecological impacts of alien species: quantification, scope, caveats, and recommendations. Bioscience. 2015;65:55–63.

28. Nentwig W, Bacher S, Pyšek P. The generic impact scoring system (GISS): a standardized tool to quantify the impacts of alien species. Environmental Monitoring and Assessment. 2016;188:315.

29. Van der Veer G, Nentwig W. Environmental and economic impact assessment of alien and invasive fish species in Europe using the generic impact scoring system. Ecology Freshwater Fish. 2014(4):646-56.

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30. Vaes-Petignat S, Nentwig W. Environmental and economic impact of alien terrestrial arthropods in Europe. NeoBiota. 2014;22:23–42.

31. Laverty C, Nentwig W, Dick JTA, Lucy FE. Alien aquatics in Europe: assessing the relative environmental and socio-economic impacts of invasive aquatic macroinvertebrates and other taxa. Management of Biological Invasions. 2015;6:341–50.

32. Novoa A, Kumschick S, Richardson DM, Rouget M, Wilson JRU. Native range size and growth form in Cactaceae predicts invasiveness and impact. NeoBiota. 2016;30:75-90.

33. Sohrabi S, Pergl J, Pyšek P, Foxcroft LC, Gherekhloo J. Quantifying the potential impact of alien plants of Iran using the Generic Impact Scoring System (GISS) and Environmental Impact Classification for Alien Taxa (EICAT). Biological Invasions. 2021;23:2435-449.

34. Evans T, Blackburn TM, Jeschke JM, Probert AF, Bacher S. Application of the Socio-Economic Impact Classification for Alien Taxa (SEICAT) to a global assessment of alien bird impacts. NeoBiota. 2020;62:123-42.

35. Defra. Wildlife management in England: a policy making framework for resolving human-wildlife conflicts (withdrawn). 2010; https://www.thenbs.com/publicationindex/documents/details?Pub=DEFRA&DocId=295502.

36. Haddaway NR, Collins AM, Coughlin D, Kirk S. The role of Google Scholar in evidence reviews and its applicability to grey literature searching. PLOS One. 2015;7:e013823.

© Crown Copyright 2025

37. Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, et al. Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). Diversity and Distributions. 2015;21:1360-63.

38. Crawley D, Coomber F, Kubasiewicz L, Harrower C, Evans P, Waggitt J, et al. Atlas of the mammals of Great Britain and Northern Ireland. The Mammal Society: Pelagic Publishing, UK; 2020. 192 p.

39. Mathews F, Kubasiewicz LM, Gurnell J, Harrower CA, McDonald RA, Shore RF. A review of the population and conservation status of British mammals: technical summary. A report by the Mammal Society under contract to Natural England, Natural Resources Wales and Scottish Natural Heritage. Peterborough: Natural England; 2018.

40. Harris S, Yalden DW. Mammals of the British Isles: handbook 4th edition. Southampton: The Mammal Society; 2008.

41. R Core Team. R: A language and environment for statistics computing. In: Computing RFfS, editor. Vienna, Austria2022.

42. Christensen R. *ordinal* - Regression Models for Ordinal Data. R package version 2023.12-4.1. 2023; https://cran.r-project.org/web/packages/ordinal/ordinal.pdf.

43. Brooks ME, Kristensen K, van Benthem KJ, Magnusson A, Berg CW, Nielsen A, et al. *glmmTMB* balances speed and flexibility among packages for zero-inflated generalised linear mixed modelling. The R Journal. 2017;9:378-400.

44. Hartig F. *DHARMa*: Residual diagnostics for hierarchical (multi-level/mixed) regression models. R package version 0.4.7. 2024; https://cran.r-project.org/web/packages/DHARMa/vignettes/DHARMa.html.

© Crown Copyright 2025

45. Bhatia S, Redpath SM, Suryawanshi K, Mishra C. Beyond conflict: exploring the spectrum of human–wildlife interactions and their underlying mechanisms. Oryx. 2020;54(5):1-8.

46. Defra. Government to end badger cull with new TB eradication strategy. 2024; https://www.gov.uk/government/news/government-to-end-badger-cull-with-new-tb-eradication-strategy#:~:text=The%20new%20strategy%20will%20mark,the%20end%20of%20this%20parliament.

47. Petrovan SO, Ward AI, P. W. Detectability counts when assessing populations for biodiversity targets. PLOS One. 2011;6:8.

48. Sainsbury KA, Shore RF, Schofield H, Croose E, Campbell RD, McDonald RA. Recent history, current status, conservation and management of native mammalian carnivore species in Great Britain. Mammal Review. 2019;49(2):171-88.

49. Gurnell J, Hare EJ. Rodents: Order Rodentia. In: Harris S, Yalden DW, editors. Mammals of the British Isles. Southampton: The Mammal Society; 2008. p. 55-199.

50. Bremner A, Park K. Public attitudes to the management of invasive non-native species in Scotland. Biological Conservation. 2007;139:306-14.

51. Taylor LH, Latham SM, Woolhouse ME. Risk factors for human disease emergence. Philosophical Transactions of the Royal Society of London Series B, Biological Sciences. 2001;356:983–89.

52. Rahman T, Sobur A, Islam S, Ievy S, Hossain J, El Zowalaty ME, et al. Zoonotic diseases: etiology, impact, and control. Microorganisms. 2020;8:1405.

53. Vapalahti O, Mustonen J, Lundkvist Å, Henttonen H, Plyusnin A, Vaheri A. Hantavirus Infections in Europe. Lancet Infectious Diseases. 2003;3:653–61.

© Crown Copyright 2025

803 54. Salisbury AM, Begon M, Dove W, Niklasson B, Stewart JP. Ljungan virus is
804 endemic in rodents in the UK. Archives of Virology. 2014;159:547-51.
805 55. Gray A, Capewell P, Zadoks R, Taggart MA, French AS, Katzer F, et al. Wild
806 deer in the United Kingdom are a potential reservoir for the livestock parasite *Babesia*
807 *divergens*. Current Research in Parasitology & Vector-Borne Diseases.
808 2021;1:100019.
809 56. Guardone L, Ebani VV, Verin R, Nardoni S, Consolazione A, Bennett M, et al.
810 Molecular detection of arthropod-borne pathogens in Eurasian badgers (*Meles meles*)
811 from the United Kingdom. Animals. 2020;10:446.
812 57. Bedenham G, Kirk A, Luhano U, Shields A. The importance of biodiversity risks:
813 link to zoonotic diseases. British Actuarial Journal. 2022;27(e10):1-9.
814 58. Puttock A, Graham HA, Cunliffe AM, Elliott M, Brazier RE. Eurasian beaver
815 activity increases water storage, attenuates flow and mitigates diffuse pollution from
816 intensively-managed grasslands. Science of the Total Environment. 2017;576:430-43.
817 59. Auster RE, Puttock A, Brazier R. Unravelling perceptions of Eurasian beaver
818 reintroduction in Great Britain. Area. 2019;52:364-75.
819 60. Macdonald DW, Johnson PJ. Foxes in the landscape: hunting, control, and
820 economics. In: Macdonald DW, Feber RE, editors. Wildlife Conservation on Farmland:
821 Volume 2, Conflict in the Countryside. Oxford: Oxford University Press; 2015. p. 20-
822 46.
823 61. Baker P, Harris S, White PCL. After the hunt: the future for foxes in Britain.
824 London: International Fund for Animal Welfare. 2006; https://mknhs.org.uk/wp-
825 content/uploads/2015/08/IFAW-after-the-hunt.pdf; 2006.

© Crown Copyright 2025

62. Sun ZS, Wan EY, Agbana YL, Zhao HQ, Yin JX, Jiang TG, et al. Global One Health index for zoonoses: A performance assessment in 160 countries and territories. iScience. 2024;27:109297.

63. Hand A. Estimating feral cat densities using distance sampling in an urban environment. Ecological Evolution. 2019;9:2699–705.

64. McDonald JL, Skillings E. Human influences shape the first spatially explicit national estimate of urban unowned cat abundance. Scientific Reports. 2021;11:20216.

65. Baker PJ, Molony SE, Stone E, Cuthill IC, Harris S. Cats about town: is predation by free-ranging pet cats Felis catus likely to affect urban bird populations? . Ibis. 2008;150:86-99.

66. Fredrikson A. Of wildcats and wild cats: troubling species-based conservation in the Anthropocene. Environment and Planning D: Society and Space. 2016;34(4):1-25.

67. Lowe S, Browne M, Boudjelas S. 100 of the world's worst invasive alien species: a selection from the Global Invasive Species database. Invasive Species Specialist Group (ISSG), International Union for Conservation of Nature. 2000; https://portals.iucn.org/library/sites/library/files/documents/2000-126.pdf.

68. Trouwborst A, McCormack PC, Camacho EM. Domestic cats and their impacts on biodiversity: A blind spot in the application of nature conservation law. People and Nature. 2019;2:235-50.

69. Kumschick S, Bacher S, Dawson W, Heikkila J, Sendek A, Pluess T, et al. A conceptual framework for prioritization of invasive alien species for management according to their impact. NeoBiota. 2012;15:69-100.

Supporting information

S1 File. Detailed description of all of the conflicts identified in the scientific literature for 48 mammals of the British Isles.

S2 Table. List of species causing conflict, including order, status, population size, body mass, biomass and type of conflicts recorded over time (pre-2014 only; both pre-2014 and 2014 to present; 2014 to present only). The median impact score (1=minimal known impact to 5=highest known impact) and confidence rating (1=low; 2=medium; 3=high) are shown after each conflict [x,x]. The highest impact scores are shown in bold.

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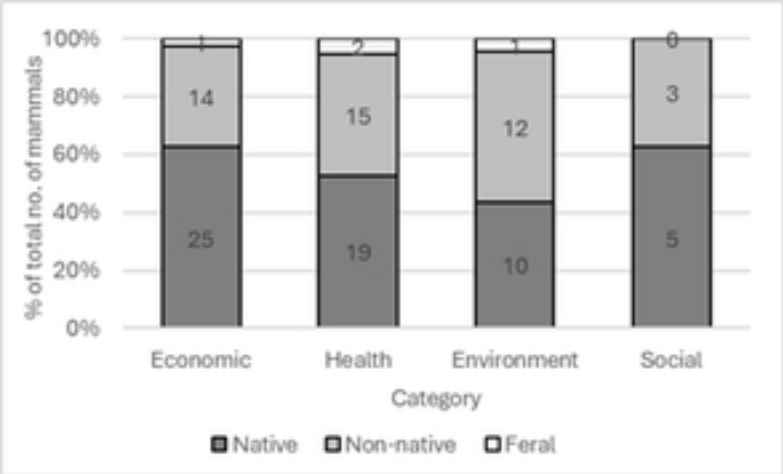
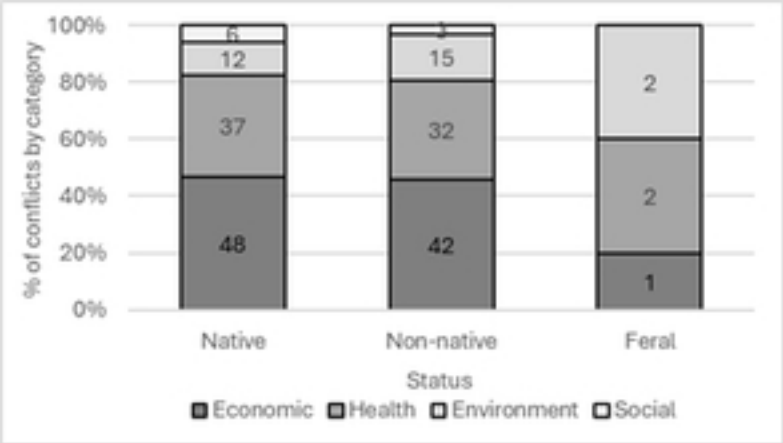
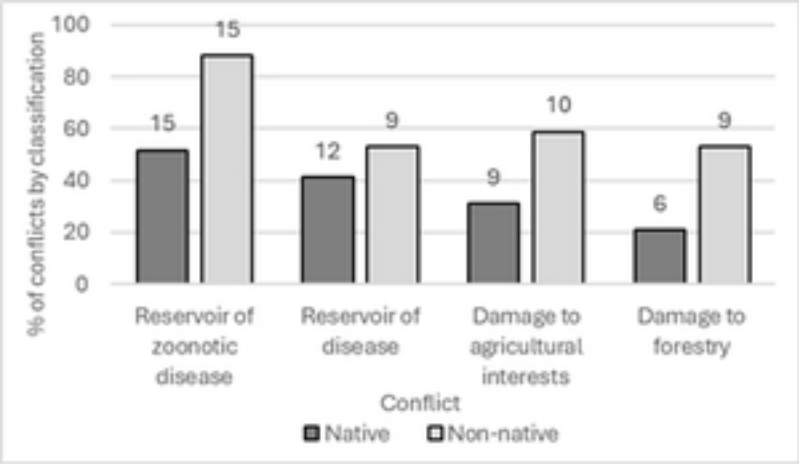

100%
80%
60%
40%
20%
0%
% of total no. of mammals
1
14
25
2
15
19
1
12
10
0
3
5
Economic
Health
Environment
Social
Category
Native
Non-native
Feral

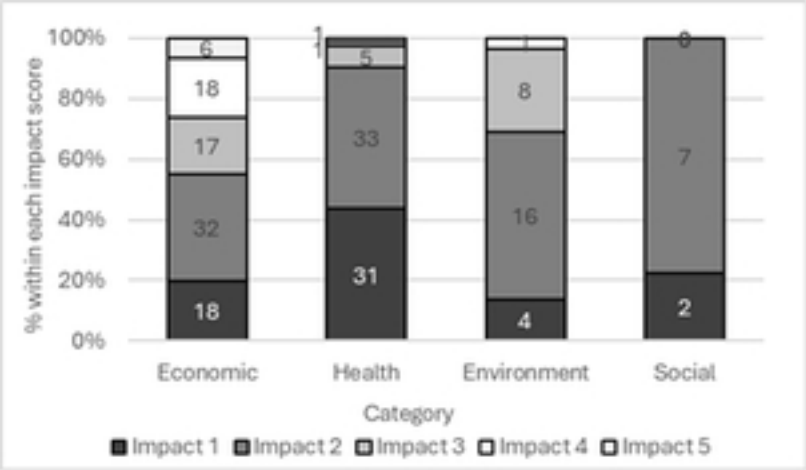
Figure


100%
80%
60%
40%
20%
0%
% of conflicts by category
6
12
37
48
3
15
32
42
2
2
1
Native
Non-native
Feral
Status
Economic
Health
Environment
Social

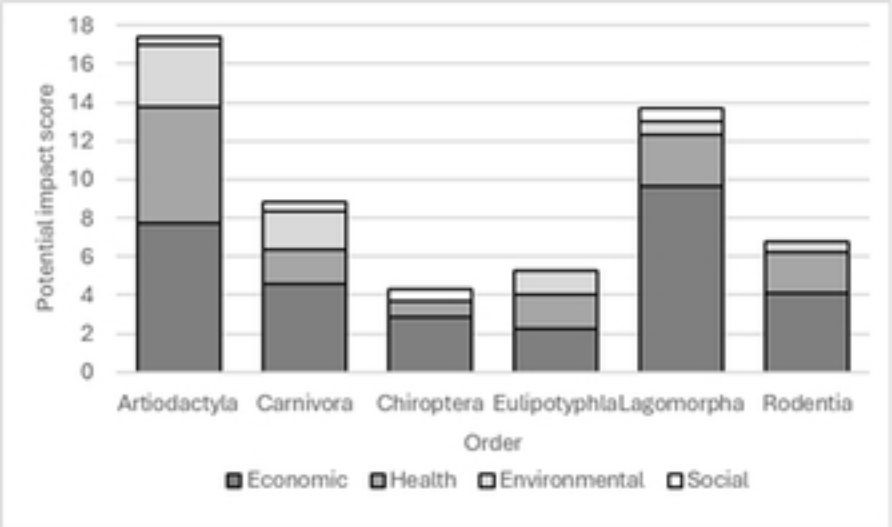
Figure


% of conflicts by classification
100
80
60
40
20
0
15
15
12
9
9
10
6
9
Reservoir of zoonotic disease
Reservoir of disease
Damage to agricultural interests
Damage to forestry
Conflict
Native
Non-native

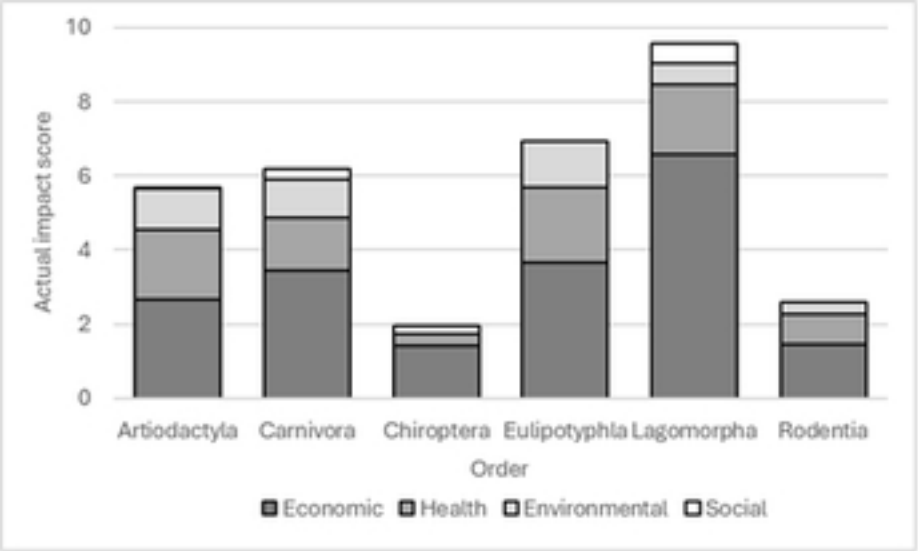
Figure


100%
80%
60%
40%
20%
0%
% within each impact score
6
18
17
32
18
1
1
5
33
31
1
8
16
4
0
7
2
Economic
Health
Environment
Social
Category
Impact 1
Impact 2
Impact 3
Impact 4
Impact 5

Figure


18
16
14
12
10
8
6
4
2
0
Potential impact score
Artiodactyla
Carnivora
Chiroptera
Eulipotyphla
Lagomorpha
Rodentia
Order
Economic
Health
Environmental
Social

Figure


10
8
6
4
2
0
Actual impact score
Artiodactyla
Carnivora
Chiroptera
Eulipotyphla
Lagomorpha
Rodentia
Order
Economic
Health
Environmental
Social

Figure