Eur J Wildl Res
DOI 10.1007/s10344-017-1084-7

ORIGINAL ARTICLE

Prioritising islands in the United Kingdom and crown dependencies for the eradication of invasive alien vertebrates and rodent biosecurity

Andrew Stanbury[1] · Sophie Thomas[1] · James Aegerter[2] · Andy Brown[3] · David Bullock[4] · Mark Eaton[1] · Leigh Lock[1] · Richard Luxmoore[5] · Sugoto Roy[6] · Stan Whitaker[7] · Steffen Oppel[1]

Received: 14 September 2016 / Revised: 2 January 2017 / Accepted: 13 January 2017

Abstract Invasive alien vertebrates (IAVs) pose a significant threat to island biodiversity worldwide, and their removal is an important nature conservation management goal. As methods advance, eradications from larger islands and of multiple species simultaneously are increasingly undertaken. Effective targeting to maximise conservation gain is important given limited resources. We build on existing prioritisation methods and use the islands of the UK and Crown Dependencies (UK) as an example of how vertebrate eradications might be prioritised and invasive-free status maintained through biosecurity. For each of the 9688 UK islands, we assessed ecological importance for native vertebrates and the anticipated impacts of the IAVs present to estimate the benefit of restoration based on the feasibility and sustainability of IAV eradications in relation to island size, human population and risk of unassisted reinvasion by swimming. As reinvasion poses a threat to the long-term benefits of eradication, we incorporated species-specific swimming distances and explored the effects of varying reinvasion probability from risk-averse to higher-risk strategies. The 25 islands that would benefit most from eradications were in Scotland, Northern Ireland and the Channel Islands. Our prioritisation method should be seen as an initial guide to identify islands that might benefit from intervention when faced with a large list of potential sites. Feasibility studies taking account of factors such as interspecific interactions, anthropogenic reinvasion, views of residents or 'social feasibility' and cost need to be undertaken before planning any eradication. We prioritised biosecurity for rat-free islands to highlight where comprehensive measures might be most beneficial.

Electronic supplementary material The online version of this article (doi:10.1007/s10344-017-1084-7) contains supplementary material, which is available to authorized users.

Keyword Invasive alien vertebrate · Eradication · Island restoration · Prioritisation · Natural reinvasion risk · Rodent biosecurity

✉ Andrew Stanbury
andrew.stanbury@rspb.org.uk

1 RSPB Centre for Conservation Science, Royal Society for the Protection of Birds, The Lodge, Sandy SG19 2DL, UK

2 National Wildlife Management Centre, Animal and Plant Health Agency, Sand Hutton YO41 1LZ, UK

3 Natural England, Unex House, Bourges Boulevard, Peterborough PE1 1NG, UK

4 National Trust, Heelis, Kemble Drive, Swindon SN2 2NA, UK

5 The National Trust for Scotland, Hermiston Quay, 5 Cultins Road, Edinburgh EH11 4DF, UK

6 IUCN, Rue Mauverney, CH-1196 Gland, Switzerland

7 Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness IV3 8NW, UK

Introduction

Invasive alien vertebrates (IAVs) pose a significant threat to island biodiversity worldwide, and their eradication is key to the successful conservation of many vulnerable species (Courchamp et al. 2003; Howald et al. 2007; Jones et al. 2016). The eradication of invasive species from islands is becoming an increasingly popular and valued restoration technique. Some large and populous islands must be targeted if this conservation tool is to be used to maximum benefit (Martins et al. 2006) and, as eradication methods have developed and improved, these are now within scope. Eradications

Published online: 04 February 2017

are often expensive and logistically challenging operations (Helmstedt et al. 2016). In order to maximise the benefits an eradication can have, by reducing the threat IAVs pose to the most threatened and vulnerable ecological communities , a rigorous and objective method to decide which islands and which IAV species should be targeted has become an increasing imperative (Brooke et al. 2007; Dawson et al. 2015; Harris et al. 2012),

Brooke et al. (2007) developed an approach to prioritising IAV eradications on islands for the benefit of seabirds, which was later expanded by Dawson et al. (2015) to encompass a broader range of 'benefit species'. Both quantified island-specific population data on species of conservation interest, and the presence of IAVs and an assessment of the damage they may cause, in order to calculate the benefit of eradication. Dawson et al. (2015) took into account which eradication operations were practically feasible in relation to island size and resident human population and assessed the merits of partial island restorations via the eradication of only those IAVs for which this was considered feasible. Helmstedt et al. (2016) used probabilities of extinction and eradication success to avoid the use of simplistic categories of 'feasibility' and 'success' constraining the range of management options available. Removing all IAVs from an island is generally the optimal restoration, as it avoids unintended indirect effects such as mesopredator or competitor release (Brooke et al. 2007; Clout and Russell 2008); however, such multi-species eradications are often not feasible.

Eradication prioritisations have been carried out for various geographic regions, archipelagos and taxonomic groups, many of which have a high proportion of endemic and globally threatened species (Brooke et al. 2007; Dawson et al. 2015; Ecosure 2009; Harris et al. 2012). Whilst islands in the United Kingdom and Crown Dependencies (henceforth referred to as UK) hold no endemic terrestrial vertebrate species and few species threatened with global extinction, they are of international importance for their breeding assemblages of seabirds and waders and many islands are, accordingly, designated as Special Protection Areas under EU legislation. Within the UK, species such as corncrake *Crex crex*, European storm-petrel *Hydrobates pelagicus*, Leach's storm-petrel *Hydrobates leucorhous*, Manx shearwater *Puffinus puffinus*, roseate tern *Sterna dougallii* and red-necked phalarope *Phalaropus lobatus*, all listed under Annex I of the EU Birds Directive, are largely confined to islands (Balmer et al. 2013, Mitchell et al. 2004). The UK islands also hold populations of European otter *Lutra lutra*, western barbastelle *Barbastella barbastellus* and Bechstein's bat *Myotis bechsteinii* (Harris and Yalden 2008), all of which are protected under the EU Habitats Directive. The Bern Convention affords further protection to some species found on UK islands, and Article 11 calls for strict control on the introduction of non-native species.

Many populations of species of conservation concern rely on predator-free islands. However, like many islands across Europe, many UK islands harbour IAVs such as brown rat *Rattus norvegicus*, feral cat *Felis catus*, European hedgehog *Erinaceus europaeus*, European rabbit *Oryctolagus cuniculus*, house mouse *Mus musculus* and American mink *Neovison vison.* Ninety islands in Europe have been successfully cleared of one or more IAVs in the past 25 years (totalling 106 eradications) (DIISE, 2016). Half of the 16 inhabited islands, and five of the ten largest islands in this suite, are in the UK. As with the rest of Europe (80 out of 106 eradications), past IAV eradication projects in the UK have largely focussed on rats as their eradication has major conservation benefits for seabirds (DIISE 2016; Booker and Price 2014; Morgan 2012). Yet, there are still many islands in the UK where IAVs have negative impacts on species of conservation interest. In addition, most UK islands currently have low levels of biosecurity in place and new invasions continue to occur. For example, stoat *Mustela erminea* became established on the main island of the Orkney archipelago in 2010 (Fraser et al. 2015), whilst brown rats reinvaded Handa more than a decade after they had been eradicated (S Rasmussen *pers comm.*) and they regularly recolonise islands within the Isles of Scilly archipelago (Heaney et al. 2008). Objective guidance is needed to decide which islands to restore next, and those that are the priority for biosecurity measures.

Unassisted movements among archipelagos can be as important as human-mediated pathways for the distribution of invasive species (Russell and Clout 2004; Tabak et al. 2015). Each IAV species has varying capacity to swim between islands; for example, among rodents and mustelids, potential swimming distances have been published as 0.5 km for house mouse, 0.75 km for black rat *Rattus rattus*, 2.0 km for brown rat and 3.0 km for stoat (Harris et al. 2012; Veale 2013). As few UK islands are isolated and unassisted reinvasion by IAVs represents a risk to the long-term benefits of restoration projects, species-specific swimming potential need to be taken into account.

Due to differences in species composition of native vertebrates and IAVs on islands across Europe, prioritisation work should preferably be undertaken at the regional rather than at the continental scale (Genovesi and Carnevali 2011). In the UK, previous prioritisation exercises have focussed on taxonomic subgroups, such as removing rats to benefit tube-nosed seabirds (Ratcliffe et al. 2009), but the biological importance of UK islands is much broader than this group and invasive species other than rats pose a significant threat.

Here, we examine and prioritise all islands of the UK for the eradication of one or more invasive mammal to benefit the most significant and threatened species populations vulnerable to IAV impacts. We made a rapid assessment of a large number of potential restoration sites to produce a shortlist for which more detailed priority criteria, such as costs and social feasibility, could be considered in a quantitative decision support framework at a later stage (Glen et al. 2013; Helmstedt et al. 2016). We therefore adopt and expand the approach used by Dawson et al. (2015) by incorporating species-specific swimming distances into the general prioritisation framework for island eradications and explore the effects of varying the probability of reinvasion. We also use the same mechanism to prioritise UK islands for enhancing biosecurity arrangements for brown rats. This species has a large negative impact on native wildlife on islands and is one of the most likely IAVs for which an incursion may go undetected. Few native species are at risk of global extinction in the UK and conservation action is often prioritised towards those that are threatened or deemed of conservation interest at more local (national or European) level. We refined existing prioritisation approaches to give additional emphasis to those taxa that are threatened at a national level.

Methods

Data collection

Island information

The scope of the study encompassed all islands situated off mainland UK. The UK Overseas Territories were excluded as they were covered in Dawson et al. (2015). We defined an island as an area where land remains above the spring high-tide line (Ordnance Survey Mastermap Mean High Water Spring line—MHWS). All 9688 'islands' we identified were distinct (i.e. surrounded by water) at low tide (Ordnance Survey Mastermap Mean Low Water Spring line) but were not necessarily connected at high tide (MHWS). For each island, the size at high water (MHWS) and the minimum distance to neighbouring islands at low tide were measured. Resident human population was also recorded (Onsgovuk. 2016; Scotlandscensusgovuk. 2016). Most islands were small, with only 506 and 148 larger than 10 and 100 ha, respectively. One hundred of the islands had a resident human population.

Benefit species

The UK's islands are of international significance for vertebrates (Birdlife International 2004, 2015; Heath et al. 2000). They hold breeding populations of one globally threatened terrestrial vertebrate (Atlantic puffin *Fratercula arctica*—vulnerable), and 11 globally near-threatened species: common eider *Somateria mollissima*, Eurasian oystercatcher *Haematopus ostralegus*, Eurasian curlew *Numenius arquata*, northern lapwing *Vanellus vanellus*, black-tailed godwit *Limosa limosa*, razorbill *Alca torda*, Dartford warbler *Sylvia undata*, meadow pipit *Anthus pratensis*, Bechstein's bat, western barbastelle and European otter. They support around 3 million breeding seabird pairs, some 80% of the UK total. At a European level, UK offshore islands hold approximately 80–90% of breeding Manx shearwaters, 50–60% of great skuas, 30–40% of common guillemots *Uria aalge*, 30% of northern gannets, 30% of European shags *Phalacrocorax aristotelis* and 20% of Leach's storm-petrel (European population figures taken from BirdLife International 2015).

All UK terrestrial vertebrates were assessed against the following three criteria:

- Globally threatened or near-threatened species on the IUCN Red List (Iucnredlistorg 2016)
- Species which form all or part of the qualifying interest of a special protection area (SPA) or special area for conservation (SAC) and were thus of central interest under European conservation legislation at the time of writing;
- Species which have 20% or more of their UK population or range on islands and either appear on one of the national priority species lists (available for England, Scotland, Wales, Northern Ireland and Jersey) or occur in internationally important numbers (e.g. at least 20% of the European breeding population found in the UK) (Eaton et al. 2015).

Sixty-six species of bird, reptile, amphibian and mammal (Supporting Information S1) met one or more of these criteria and were selected for inclusion into our prioritisation as they would potentially 'benefit' from the removal of one or more IAVs.

It is highly likely that some populations of species of conservation concern ('benefit species') have been extirpated on islands due to the presence of IAVs. As some IAV populations have been present for a century or more, there was little or no reliable information on population levels of native species prior to the arrival of IAVs and few documented extirpations. As such, our prioritisation focused on current or recent data, though any known extirpations were also recorded. The database of the presence and abundance of benefit species on islands was built on data obtained from over 90 published sources. When available, the most recent comprehensive national survey for a species was used as the primary source. To gauge the significance of each island for each benefit species, island-specific population data were recorded whenever available but presence was used when no quantitative data existed. The latter mostly related to the UK's 8674 small islands of less than 1 ha. Breeding presence was assigned to 'confirmed', 'probable' and 'possible' categories (Supporting Information S2) based on the certainty of existing information. Known extirpated populations were expressed as 'potentially present' on an island.

Invasive alien vertebrates (IAV)

We included 22 IAVs which were known either to have a detrimental impact on at least one of the selected benefit species in the UK or to adversely impact on a similar species elsewhere in the world (Table 1). All IAVs identified as being potentially problematic in the UK were non-flying terrestrial mammals. Data relating to IAV presence on each island were accessed from a variety of sources such as published and grey literature, the National Biodiversity Network and local expert opinion. IAV presence on an island was classified as either confirmed or probable depending on the quality of information available. These categories were analogous to the classification for benefit species. In the absence of conclusive data, the presence of feral cats and house mice was assumed probable on islands with a human population of 25 or more. The presence of American mink was inferred from National Biodiversity Network 10-km^2 grid cell distribution data, with all islands within occupied squares classified as 'probably' occupied due to the species' ability to swim considerable distances in the open sea. Some IAVs, such as American mink, are capable of inflicting damage on islands on which they are not resident but visit in the course of daily or seasonal movements. As a result, we made no assumptions over whether IAVs were resident or transient on islands.

Prioritising islands for vertebrate eradications

We used the method developed by Dawson et al. (2015). This first assessed an island's potential conservation value (PCV), which assumes the complete removal of all IAVs from the island, and provides an indication of islands where pressures from IAVs may be greatest. The method also calculates a realistic conservation value (RCV) resulting from the eradication of only those IAVs for which eradication is considered feasible and sustainable. We expand on the approach used by Dawson et al. (2015) by incorporating species-specific unassisted reinvasion potential (natural reinvasion risk—NRR) for each IAV.

Potential conservation value

An island's potential conservation value (PCV) was determined using four measurable attributes of each benefit species: (1) global threat assessment, (2) the national population trend, (3) significance of the population on an island in a national or European context (the 'irreplaceability' score) and (4) severity of impacts inflicted by all IAVs present (see Supporting Information S3 for the scoring system used for the first three). The severity of impact was classified in three categories, depending on whether an IAV had no impact on a native species (0), small to moderate impact that would reduce population size but allow the native species to persist (1) or a severe impact that would eventually lead to the local extinction of the native species (2).

We followed Dawson et al. (2015) and scored the first three categories on both a linear and logarithmic scale to address the arbitrariness of assigning quantitative values to normative categories (Game et al. 2013) and because quantitative extinction risk probabilities were not available for all species on all islands (Helmstedt et al. 2016).

The PCV for each island i was calculated by summing the conservation values (Supporting Information S3) for each species s present on the island using the following equation:

$$\mathrm{PCV}_i = \left(\sum_1^s GT_{s,i} \times NT_{s,i} \times I_{s,i} \times Z_{s,i}\right) + 0.5\left(\sum_1^p GT_{p,i} \times NT_{p,i} \times I_{p,i} \times Z_{p,i}\right)$$

where GT is global threat of each benefit species s occurring on island i, NT is national trend, I is irreplaceability and Z is the maximum severity of impact of any IAV on each benefit species. The prioritisation focussed on the benefit species known to be present on an island. However, given that the re-establishment of locally extirpated species post-IAV eradication may occur (Jones et al. 2016; Morgan 2012), populations p whose presence was defined as either possible or potential (e.g. extirpated species which could recolonise) were given half the weight of extant species to reflect possible conservation gain. This approach assumes that 50% of possible colonisations will occur after successful eradication, which is a reasonable assumption for islands close to source populations such as the UK (Buxton et al. 2014, Jones et al. 2016).

Realistic conservation value

An island's potential conservation value can only be realised if all IAVs are eradicated. This is often not achievable. The same process used to determine PCV was used to calculate an island's RCV, which only considers the conservation benefits of removing IAV populations which were deemed feasible to eradicate. The global Database of Island Invasive Species Eradications (DIISE 2016) was used as a guide to what has been achieved to date elsewhere in the world, and we set benchmarks based on the largest successful eradication globally for each IAV in terms of both island size and human population (Table 1). Where data were lacking for individual IAV species, these were inferred from taxonomically related species (e.g. ungulate, mustelid, rodent).

When calculating RCV, the severity of impact score used for each benefit species was the highest of those invasive species where eradication was not considered feasible. This

Table 1 A list of invasive alien vertebrate species occurring on UK islands known, or suspected, to negatively affect at least one benefit vertebrate species on these islands

IAV type	Common name	Scientific name	Feasible island size for eradication (ha)[a]	Feasible human population size for eradication[a]	Maximum potential swimming distance (m)[b]	% of islands (>10 ha) in UK with confirmed or probable presence
Ungulates	Fallow deer	*Dama dama*	58,041	10,000	7000[e]	1.0
	Reeves' Muntjac	*Muntiacus reevesi*	58,041	10,000	7000[e]	0.4
	Red deer	*Cervus elaphus*	58,041	10,000	7000[e]	1.6
	Roe deer	*Capreolus capreolus*	58,041	10,000	7000[e]	0.8
	Sika deer	*Cervus nippon*	58,041	10,000	7000[e]	0.6
	Feral goat	*Capra hircus*	58,041	10,000	0	4.9
	Feral sheep	*Ovis aries*	58,041	10,000	0	1.0
Mustelids	American mink	*Neovison vison*	31,616	10,000	6500[d]	22.5
	Feral ferret	*Mustela furo*	3820	100	3000[f]	3.8
	Stoat	*Mustela erminea*	3820	100	3000[f]	4.0
	Weasel	*Mustela nivalis*	3820	100	3000[f]	1.0
	Pine marten	*Martes martes*	3820	100	3000[f]	0.4
	European badger	*Meles meles*	3820	100	0	1.2
Rodents	Brown rat	*Rattus norvegicus*	12,873	1000	2000[c]	20.9
	Black rat	*Rattus rattus*	12,873	1000	750[c]	1.6
	House mouse	*Mus musculus*	12,873	1000	500[c]	19.0
	Wood mouse	*Apodemus sylvaticus*	12,873	1000	500[c]	12.8
	Grey squirrel	*Sciurus carolinensis*	12,873	1000	1000[g]	0.6
	European rabbit	*Oryctolagus cuniculus*	12,873	100	0	23.7
Others	European hedgehog	*Erinaceus europaeus*	2311	100	200[d]	11.7
	Red fox	*Vulpes vulpes*	90,249	1000	1600[h]	1.8
	Feral cat	*Felis catus*	29,305	1000	0	16.6

For each species, eradication feasibility was assessed against island size and human population size from the largest successful global eradication; reinvasion risk was considered based on the maximum recorded swimming distance

[a] DIISE (2016) was used as a guide to what eradications have been achieved to date globally. Thresholds for island size and human population were taken as the largest island from which the IAV (or very similar species) has been eradicated (assessed 30 June 2016). Only successful whole-island eradications with satisfactory or good quality data were used. Stoats were eradicated from the closely neighbouring islands of Rangitoto and Motutapu (NZ) in one project; therefore, their combined area was used for mustelids. To date, European hedgehog has only been successfully eradicated from three islands globally, none of which were uninhabited. For this species, we used a human population threshold of 100

[b] Species with the potential to disperse to islands unassisted were assigned a maximum recorded swimming distance

[c] Harris et al. (2012)

[d] S Roy *pers. Comm.*

[e] Mulville (2010) and Serjeantson (1990)

[f] Veale (2013)

[g] C Shuttleworth *pers. Comm.*

[h] Abbott (2000)

approach ensured that an island would rank less highly if only a subset of IAV could be eradicated. For example, on an island where American mink and brown rats affected a local wader population, with American mink having a stronger impact than rats, the eradication of both species simultaneously would achieve the greatest eradication benefit; if only American mink could be eradicated but brown rat could not, the eradication benefit would be lower reflecting the ongoing damage rats would inflict upon benefit species. If only brown rats could be eradicated, but American mink could not, then there would be no eradication benefit at all because the native species would still be exposed to the stronger impact of American mink. This approach may underestimate the benefit of a partial IAV eradication if only the less harmful IAVs are eradicated.

Natural reinvasion risk

Reinvasion can occur at any time and can potentially nullify the benefits of eradication. Whilst anthropogenic pathways can be identified and the risks mitigated to some degree, unassisted reinvasion through animals swimming across from adjacent land masses is more difficult to prevent (Brooke et al. 2007; Oppel et al. 2011). This is particularly challenging in the UK where most islands are close to the mainland or large islands from where IAVs could quickly reinvade. As well as assessing the feasibility of eradicating an IAV from an island, we measured the distance between each island and nearby IAV populations that could act as sources for reinvasion. If an island was assessed to be too close to a neighbouring IAV population where eradication was not currently possible (due to the size of the island or its human population), then that eradication was considered unlikely to yield lasting benefits due to the risk of reestablishment via natural pathways, and we set eradication feasibility to zero for that IAV on that island. If an island was close to a potential source IAV population that could be eradicated, eradication was considered feasible.

The capacity to disperse unassisted between islands varies between species. Mustelids, for example, can move much greater distances than rodents can. Dawson et al. (2015) incorporated NRR only for rodents, for which a maximum swimming distance of 2 km was used (based on Russell et al. 2008a, 2008b). However, many IAVs are known to be able to swim much greater distances and thus present a reinvasion risk for which mitigation is very difficult. To account for this, we allocated species-specific maximum recorded swimming distances to those species considered to have a propensity to swim (Table 1).

Given that the probability of reinvasion declines with increasing distance from the source population (Harris et al. 2012), the maximum recorded swimming distance of a species (Table 1) may be an unlikely event, only achievable under favourable local conditions. There is, thus, a trade-off between considering eradications unsustainable and the actual risk of reinvasion. To inform this, we explored the effects of varying reinvasion probabilities on the prioritisation by using three approaches: (i) excluding NRR and treating reinvasion as a biosecurity consideration that would merely increase the financial cost of a project—a high-risk approach; (ii) using the maximum recorded swimming distance for IAVs—a risk-averse approach or (iii) halving the maximum recorded swimming distances (e.g. using a 1-km distance for brown rats, rather than their known swimming potential, but rarer, 2 km)—a medium-risk approach. For our final prioritisation, the medium-risk scenario was deemed an acceptable risk for reinvasion.

Calculating an island's eradication benefit and the final island ranking

The eradication benefit (EB) took into account that, on many islands, it may not be feasible or sustainable to eradicate all IAVs ($EB_i = PCV_i - RCV_i$). The islands with the largest EB were considered top priorities for eradication. We followed Dawson et al. (2015) and calculated EB for each island eight times to account for the different combinations of log and linear scales for global threat, national trend and 'irreplaceability'. All islands were then ranked eight times according to their scores, and the median of these ranks was then used to determine the overall priority for IAV eradication (examples are shown in Supporting Information S4). All calculations were performed in R 3.1.0 (R Development Core Team 2015) based on the code provided by Dawson et al. (2015).

Prioritising island biosecurity

Even on islands where the risk of natural reinvasion via swimming is negligible, the risk of transporting IAVs, particularly rodents, by anthropogenic means can be high. We used the databases to produce a priority list of islands currently free from IAVs where the installation of appropriate biosecurity measures ought to be a paramount conservation concern. Here, we use brown rat as an example and ranked islands according to the difference in conservation value that would ensue if brown rats had invaded all islands currently free of the species. Other IAVs known to be present on an island remained in the analysis; hence, islands with no IAV present would be considered to be more heavily impacted by the arrival of rats compared to an island where, for example, mink were already present. We did not want our biosecurity ranking to be affected by eradication constraints and so thresholds for island and human population size were excluded from the analysis.

Results

We recorded the confirmed or probable presence of 2202 populations of the 22 focal IAVs on UK islands. European rabbit was the most widespread followed by American mink, brown rat, house mouse and feral cat. Over half (59%) of the 14,803 benefit species, island populations were assessed as being potentially affected by at least one IAV present on the same island.

Potential conservation value

The prioritisation exercise encompassed 955 islands where IAVs potentially affected benefit species, and an eradication may thus be beneficial. The PCV ranking highlighted where IAVs had the highest impact on species of conservation interest. The ten highest ranked islands were (area and resident human population shown in parentheses): Mainland Orkney (51,716 ha, 17,166 people), Mainland Shetland (95,186 ha, 18,765 people), Lewis and Harris (215,266 ha, 21,031 people), Foula (1302 ha, 38 people), Fetlar (4042 ha, 61 people), Unst (12,136 ha, 632 people), North Uist (33,696 ha, 1502 people), Tiree (7920 ha, 653 people), Isle of Skye (163,622 ha, 10,008 people) and Westray (4742 ha, 588 people) (Supporting Information S5). These, mainly large, islands hold important biodiversity and have one or more of the following high-impacting IAVs present: brown rat, feral cat, stoat or American mink.

Realistic conservation value and eradication benefit

Of the top ten islands ranked for their PCV score, eradication of all IAVs was only considered feasible on one (Foula). For the other nine, island or human population size exceeded the eradication thresholds for at least one IAV. This illustrates the limitations of island restoration via IAV eradication for many sites of conservation importance given current methods and achievements. However, as methods advance, eradication may become a realistic goal for some sites where interventions were previously limited to long-term control of IAVs.

Table 2, column a, presents the 25 highest ranked islands for Eradication Benefit, based on what was currently considered feasible in terms of island size/human population and excluding natural reinvasion risk. When the risk of unassisted reinvasion was considered to be medium (Table 2, column b: half the maximum IAV swimming distances), three islands (Handa, Brownsea, Caldey) were excluded from the prioritisation and a further three islands (Little Cumbrae, Bressay and Iona) ranked outside the top 25, as they were too close to ineradicable source populations for some species and so could only benefit from partial restoration initiatives. Moving between a medium risk to a risk-averse approach for reinvasion (Table 2, column c) did not substantially affect the overall ranking but led to one further island (Inchmarnock) being excluded from the prioritisation.

For our further assessment, we accepted a medium risk of reinvasion (Table 3, Fig. 1a and Supporting Information S5). All but two of the 25 islands where IAV eradication was deemed to yield the greatest benefit were in Scotland, with Rathlin Island (Northern Ireland) and Herm (Channel Islands) the exceptions.

Island biosecurity

The same process was used to identify islands where biosecurity measures are important to protect their rat-free status (Table 4, Fig. 1b and Supporting Information S5). This highlighted the importance for wildlife of the remote St Kilda archipelago, islands off the Welsh coast, Coquet and the Farne Islands off the northeast coast of England and those in the Shetland and Orkney archipelagos.

Discussion

Our assessment represents the first comprehensive region-wide IAV eradication prioritisation of UK islands and offers a platform from which we can start to conduct more focussed viability and feasibility assessments. We built on and expanded existing approaches (Brooke et al. 2007; Ratcliffe et al. 2009; Dawson et al. 2015) by incorporating species other than seabirds and national trends in addition to global threat, integrating species-specific dispersal of IAVs and exploring the impacts of varying reinvasion probability to create more and less risk-averse priority lists. Because our prioritisation did not include financial costs, social acceptability, legal ramifications and complexities, further work is required before operational plans can be developed to eradicate IAVs from islands to safeguard vulnerable native biodiversity.

The level of reinvasion risk considered acceptable for a given island is subjective and will ultimately depend on local circumstances. We are aware, for example, that the highest priority island in Wales, Caldey, is subject to an ongoing restoration initiative (Rev K Simpson *pers comm.*) although it drops from our priority list when reinvasion risk is considered. Whilst IAVs have varying natural dispersal abilities (Harris et al. 2012; Tabak et al. 2015), few data are available on the nature of the relationships between distance and invasion probability. Maximum recorded swimming distances may be considered extreme and rare events. For example, Tabak et al. (2015) showed that the probability of brown rats occurring on islands in the Falkland Islands that were more than 1 km from a source population was less than 5%; this compares with a potential swimming distance of 2 km for this species (Harris et al. 2012; Russell et al. 2008a). We selected half the maximum recorded swimming distance as an acceptable risk for unassisted reinvasion for our study because choosing a more conservative distance that considered extreme events that are only possible under favourable tidal currents or water temperatures might exclude islands where eradication could yield substantial benefits.

The incorporation of species-specific natural reinvasion risk indicated that some islands that would otherwise be a priority may be unsuitable for IAV eradication. These islands may require alternative IAV management techniques, such as sustained or pulsed control, which may be more effective in the short term than striving for complete eradication. One example highlighted was Handa, which lies 350 m off the northwest coast of the Scottish mainland. Brown rats were eradicated from this significant seabird island in 1998 with apparent benefits for Atlantic puffin, Arctic tern *Sterna paradisaea*, common tern *S. hirundo*, Eurasian oystercatcher and ringed plover *Charadrius hiaticula* (Stoneman and Zonfrillo 2005). The island remained rat-free for over a decade before an incursion of unknown origin (and subsequent reestablishment) occurred (S Rasmussen *pers comm.*). Island reinvasion might have been avoided with more comprehensive and better resourced biosecurity and rapid response arrangements. The arbitrary nature of deciding when the reinvasion risk is too great to attempt an eradication, and hence when control options might be more appropriate, could be circumvented if the cost of comprehensive biosecurity including rapid response measures was incorporated into the island prioritisation (Helmstedt et al. 2016).

Table 2 Top 25 islands as prioritised for invasive alien vertebrate eradication in the UK based on eradication benefit, considering different levels of risk for natural reinvasion

A		B		C	
Rank position	Island	Rank position	Island	Rank position	Island
1	Foula, Shetland	1	Foula, Shetland	1	Foula, Shetland
2	Fair Isle	2	Fair Isle	2	Fair Isle
3	Westray, Orkney	3	Westray, Orkney	3	Westray, Orkney
4	Rathlin Island, Northern Ireland	4	Rathlin Island, Northern Ireland	4	Rathlin Island, Northern Ireland
5	Rousay, Orkney	4	Rousay, Orkney	5	Garbh Eilean and Eilean an Taighe, Shiants
6	Garbh Eilean and Eilean an Taighe, Shiants	4	Garbh Eilean and Eilean an Taighe, Shiants	5	Unst, Shetland
7	Colonsay and Oronsay, Inner Hebrides	7	Colonsay and Oronsay, Inner Hebrides	5	Yell, Shetland
7	**Handa Island**	7	Unst, Shetland	8	Colonsay and Oronsay, Inner Hebrides
9	Unst, Shetland	9	Yell, Shetland	9	Rum, Small Isles
10	Yell, Shetland	10	Rum, Small Isles	10	Papa Westray, Orkney
11	Papa Westray, Orkney	11	Papa Westray, Orkney	11	Fetlar, Shetland
12	Rum, Small Isles	12	Fetlar, Shetland	11	Inchkeith, Forth Estuary
13	Fetlar, Shetland	12	Inchkeith, Forth Estuary	13	Hoy, Orkney
14	Inchkeith, Forth Estuary	14	Hoy, Orkney	14	Tiree, Inner Hebrides
15	Gairsay, Orkney	15	Flotta, Orkney	15	Rousay, Orkney
16	Hoy, Orkney	16	Tiree, Inner Hebrides	16	Stronsay, Orkney
16	**Little Cumbrae Island, Clyde Island**	16	**Inchmarnock, Clyde Islands**	17	Eilean Mhuire, Shiant Islands
18	**Bressay, Shetland**	18	Stronsay, Orkney	17	Gairsay, Orkney
19	Tiree, Inner Hebrides	18	Eilean Mhuire, Shiant Islands	17	Muck, Small Isles
19	Flotta, Orkney	20	Gairsay, Orkney	20	North Ronaldsay, Orkney
21	Inchmarnock, Clyde Island	20	North Ronaldsay, Orkney	21	Housay, Out Skerries
22	**Iona, Inner Hebrides**	22	Muck, Small Isles	22	South Havra, Shetland
23	**Caldey Island, Wales**	23	Housay, Out Skerries	23	Eday, Orkney
24	Eilean Mhuire, Shiant Islands	24	South Havra, Shetland	23	Flotta, Orkney
25	**Brownsea Island, Poole Harbour**	25	Herm, Channel Islands	25	Sanday, Orkney

The three scenarios assume that (a) no natural reinvasion through swimming takes place (high-risk approach), or that natural reinvasion is possible up to (b) half the maximum recorded swimming distance (medium-risk approach), or (c) the maximum recorded swimming distance (very risk-averse approach). Islands shown in bold in columns a and b were eliminated from the top-priority list when different levels of natural reinvasion risk were considered to affect eradication feasibility

Table 3 Top 25 islands prioritised for invasive alien vertebrate eradication in the UK based on the eradication benefit of feasible and sustainable eradications and a medium-risk approach from natural reinvasion (scenario Table 2 column b)

Rank position	Island	Resident human population	Island area (ha)	No. of benefit sp. found on island	No. of sp. that exceed 1% of UK population or range	IAV presence
1	Foula, Shetland	38	1302	26	8	Fc[a], Hm[a], Er[a], Wm[a], Eh[a]
2	Fair Isle	68	786	28	9	Fc[a], Hm[a], Wm[a], Er[a]
3	Westray, Orkney	588	4742	35	8	Fc[a], Hm[a], (Er[a]), (Eh[a])
4a	Garbh Eilean and Eilean an Taighe, Shiants	0	141	17	4	Bl[a]
4b	Rousay, Orkney	216	4697	31	4	Br[a], Fc[a], Hm[a], (Er[a])
4c	Rathlin Island, Northern Ireland	100	1438	25	3	Br[a], Fc[a], Ff[a], Fg[a], Hm[a], Wm[a], Er[a]
7a	Colonsay and Oronsay, Inner Hebrides	132	4549	29	5	Br[a], Fc[a], Fg[a], Hm[a], Wm[a], (Er[a])
7b	Unst, Shetland	632	12,135	32	10	Br[a], Fc[a], Hm[a], (Er[a]), (Eh[a])
9	Yell, Shetland	966	21,103	32	7	Fc[a], (Hm[a]), (Eh[a]), (Er[a])
10	Rum, Small Isles	22	10,726	26	3	Br[a], Fg[a], Hm[a], Wm[a]
11	Papa Westray, Orkney	90	858	32	2	Hm[a], Er[a], Fc[b]
12a	Fetlar, Shetland	61	4042	34	9	Fc[a], Hm[a], Wm[a], Er[a], (Eh[a])
12b	Inchkeith, Forth Estuary	0	23	16	2	Br[a], Hm[a], Er[a]
14	Hoy, Orkney	419	14,360	32	9	Fc[a], (Er[a]), (Br[a]), (Eh[a]), (Hm[a]), (Wm[a])
15	Flotta, Orkney	80	938	27	1	Br[a], Fc[a], Hm[a], Eh[a], Er[a]
16a	Tiree, Inner Hebrides	653	7920	28	8	Br[b], Fc[b], Wm[a], Hm[b], (Eh[a])
16b	Inchmarnock, Clyde Islands	0	247	17	1	Br[b], Hm[b], Am[b], Er[b]
18a	Stronsay, Orkney	349	3362	27	3	Br[a], Fc[a], Hm[a], Wm[a], Er[a], (Eh[a])
18b	Eilean Mhuire, Shiant Islands	0	32	14	3	Bl[a]
20a	Gairsay, Orkney	3	270	26	2	Fc[a], Br[a], Er[a]
20b	North Ronaldsay, Orkney	72	766	22	1	Fc[a], Hm[a], Wm[a], Eh[a], Er[a]
22	Muck, Small Isles	27	523	22	0	Br[a], Wm[a], Fc[b], Hm[b]
23	Housay, Out Skerries	50	155	20	0	Br[a], Fc[b], Hm[b], Er[b]
24	South Havra, Shetland	0	58	22	0	Fc[b]
25	Herm, Channel Islands	60	143	11	1	Bl[a] Br[a], Wm[a] Fc[b], Hm[b], Er[b],

All islands, except Rathlin (Northern Ireland) and Herm (Channel Islands), are in Scotland. Brackets denote that the species is currently deemed ineradicable on that island

Fc feral cat, *Br* brown rat, *Bl* black rat, *Hm* house mouse, *Wm* wood mouse, *Er* European rabbit, *Am* American mink, *Eh* European hedgehog, *Ff* feral ferret, *Fg* feral goat

[a] IAV presence: confirmed

[b] IAV presence: probable

Social feasibility, accidental or deliberate reintroduction along anthropogenic pathways and terrain complexity were not incorporated into the assessment of eradication feasibility because no standardised approaches were available, and anthropogenic reinvasion pathways can be identified and often mitigated to a large extent via biosecurity arrangements. Our prioritisation aimed, therefore, at identifying a list of priority islands with the expectation that these could then be examined in greater detail to assess such island-specific attributes against the costs of an actual eradication programme (or suite of programmes). Our approach, using simple classifications and the caveats associated with them, is suitable to identify a subset of islands for which more detailed assessments can be undertaken before planning an eradication. As a result of our rapid assessment, the UK's nearly 10,000 islands have been narrowed down to a manageable subset where a tangible conservation benefit from removing IAVs is highly likely. We chose an optimistic approach, whereby we were more willing to accept a Type II error identifying an island that may not prove to be feasible upon deeper investigation, rather than rejecting an island that may in fact be truly feasible, as this was appropriate at the broad-scale conservation planning stage.

Few of the islands that appear in our prioritisation are remote and isolated. Although our prioritisation considered every geographically discrete island separately, most exist as part of island groups or archipelagos. In practice, it may be more efficient to eradicate IAVs from whole island groups to reduce the risk of reinvasion. This is the most likely option for the highest-priority English islands (Bryher, Samson, St Martin's and Tresco), all of which lie within the Isles of Scilly archipelago and pose considerable risks to each other of reinvasion by brown rats. Indeed, Samson has been cleared and reinvaded a number of times presumably by rats from neighbouring islands (Heaney and St Pierre 2015).

Most (20 of the top 25) priority islands have resident human populations and are connected to other islands or the mainland by regular boat or plane traffic. Eradicating IAVs from inhabited islands entails several social, cultural, operational and economic challenges (Brooke et al. 2007; Ogden and Gilbert 2009; Oppel et al. 2011) and to date, eradications (especially of rodents) have tended to focus on uninhabited ones. However, there is a general appreciation of the considerable challenge inhabited islands pose to the future of island restoration and the impending need to address this (Glen et al. 2013), especially as restoration is

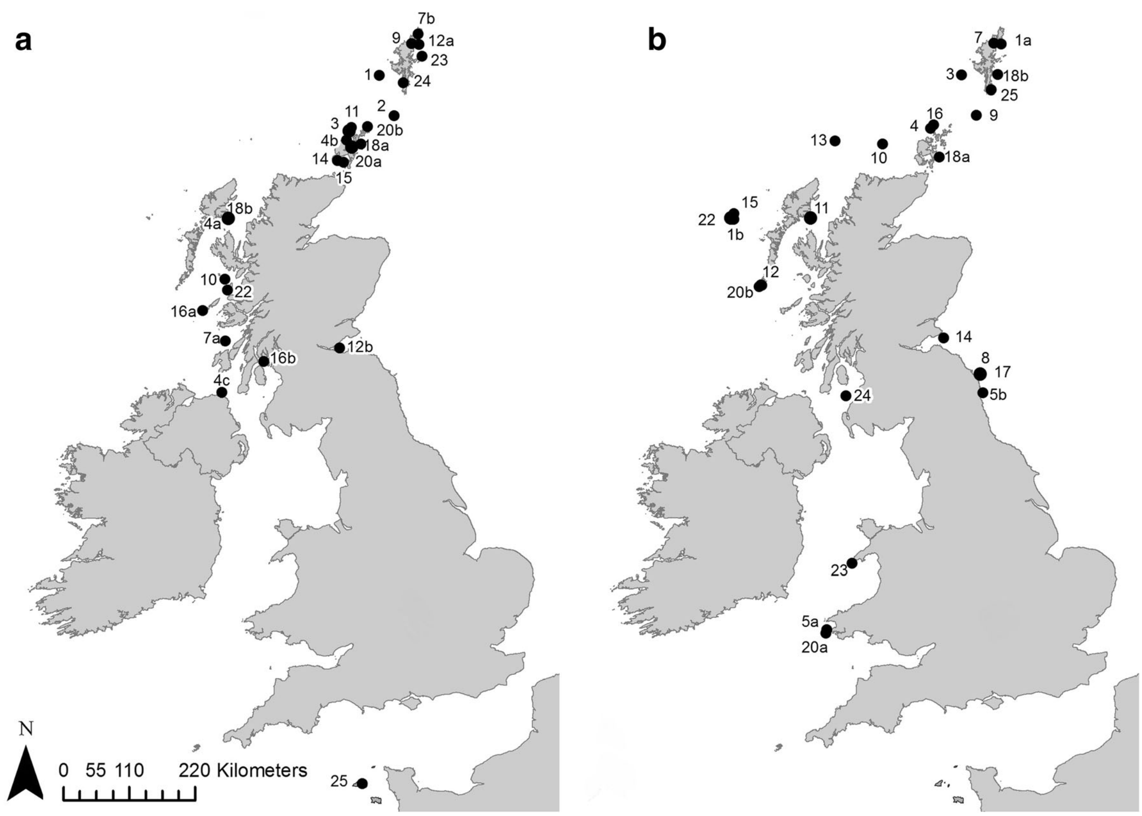

Fig. 1 Location of the top 25 islands prioritised for **a** invasive alien vertebrate eradication and **b** brown rat biosecurity measures in the UK based on their eradication benefit (see Tables 3 and 4 for identifying numbers)

achieved on more uninhabited sites. Half of all successful European eradications on inhabited islands have taken place in the UK, including St. Agnes and Gugh, the largest community-led brown rat eradication in the world, in which all of the island's 84 residents were supportive. Such unanimity may not always be forthcoming, especially on more populous islands. For some eradication proposals, divergent opinions of residents may effectively block a restoration attempt. The resources needed to gain sufficient community support may be considerable and have in the past been underestimated. More than a decade of preparatory work laid the foundations for the St. Agnes and Gugh eradication attempt, and we consider this a reasonable timescale to anticipate for similar projects.

Closer inspection of some islands may reveal that the eradication of one or several IAVs currently considered feasible and likely to deliver ecological benefit may still not be possible. For example, proposed removal of the European hedgehog from islands where it is a non-native invasive species encountered a significant obstacle in the lack of precedence for socially acceptable and cost-effective removal, despite recognition of the high levels of damage caused by this species to ground-nesting birds. Proposals to eradicate feral cats are also likely to prove unpopular in the UK. Besides socioeconomic factors that may affect the feasibility of eradications, the potential consequences of removing only a subset of invasive species must be considered carefully at the island level. A common but difficult problem is understanding the ecological interactions between multiple invasive and native species and the consequences of removing only some of them. The eradication of one invasive species may increase the adverse effects of another on native island biodiversity (Ruscoe et al. 2011; Hervias et al. 2013; Glen et al. 2013). Our analysis did not take into account indirect impacts such as prey competition between native and non-native predators, as this would have required obtaining data on all species present on each island rather than just benefit species and IAVs and considering a multitude of hypothetical interactions. The likely ecological impacts of removing only selected invasive species must be examined carefully for priority islands where only the RCV rather than full PCV can be achieved.

Many of the islands that appear in our final priority list are larger or have more human inhabitants than those from which IAVs have been successfully removed in the UK. For some species, such as American mink, UK initiatives (Roy et al. 2015) are already operating at or beyond the current global benchmark: our analysis can be easily re-run as and when global benchmarks are exceeded, such as if and when mink eradication from Lewis and Harris (215,266 ha) is confirmed. For others, the global benchmarks use removal methods that have not been deployed in the UK to date, such as the aerial

Table 4 Top 25 islands in the UK prioritised for brown rat biosecurity measures

Rank position	Island	Country	Resident human population	Island area (ha)	No. of sp. that exceed 1% of UK population or range
1a	Fetlar, Shetland	Scotland	61	4042	9
1b	Hirta and Dun, St Kilda	Scotland	0	661	8
3	Foula, Shetland	Scotland	38	1302	8
4	Westray, Orkney	Scotland	588	4742	8
5a	Skomer Island, Pembrokeshire	Wales	2	291	6
5b	Coquet Island	England	0	8	6
7	Yell, Shetland	Scotland	966	21,103	7
8	Inner Farne, Farnes	England	0	13	6
9	Fair Isle	Scotland	68	786	9
10	Sule Skerry	Scotland	0	7	4
11	Garbh Eilean and Eilean an Taighe, Shiants	Scotland	0	141	4
12	Mingulay, Outer Hebrides	Scotland	0	647	3
13	Sule Sgeir and Rona	Scotland	0	115	4
14	Isle of May, Forth Estuary	Scotland	0	53	9
15	Boreray, St Kilda	Scotland	0	86	3
16	Papa Westray, Orkney	Scotland	90	858	2
17	Brownsman and Staple, Farnes	England	0	11	4
18a	Copinsay, Orkney	Scotland	0	77	3
18b	Isle of Noss, Shetland	Scotland	0	321	4
20a	Skokholm Island, Pembrokeshire	Wales	2	99	3
20b	Berneray, Outer Hebrides	Scotland	138	212	2
22	Soay, St Kilda	Scotland	0	97	4
23	Bardsey Island	Wales	11	179	2
24	Ailsa Craig, Clyde Islands	Scotland	0	89	3
25	Mousa, Shetland	Scotland	0	171	1

broadcast of rodenticides. Operating within the current regulatory arena, the UK has developed a considerable track history of successful ground-based rodent eradications, including (on Canna and Sanday, 1317 ha) the second largest to be achieved globally (DIISE 2016). The largest, on Langara, Canada (3105 ha), demonstrates that ground-based operations can be scaled up if sufficient resources and labour are available; however, the cost of manual baiting on larger islands will rapidly surpass that of aerial operations, and opting for the least economical approach must be challenged when resources for conservation are limited. Seven of the 17 top-priority UK islands that would require rat eradication as part of their restoration are substantially larger than Langara. The main restriction to an aerial operation in the UK emanates from the EU Biocidal Product Regulation (BPR, Regulation (EU) 528/2012) with perceived risk to non-target species and concern over bioaccumulation of toxins. However, aerial broadcast (of the highly potent second-generation anticoagulant brodifacoum) has been deployed on at least three islands within the EU (Sa Dragonera, Spain; Montecristo and Molara, Italy (DIISE 2016)), and thus, this technique could be considered for the UK providing there is appropriate consideration and mitigation of the risks. Our priority ranking suggests that there are significant benefits of considering operations on large islands which may require the use of aerial bait applications and whilst it may be bureaucratically challenging to achieve, we believe that this study supports its consideration and that a general regulatory constraint should not inhibit the potential optimisation of conservation action or diminish the ambition of conservation planning at either site or national scales, especially where the benefits are significant and the risks well managed. In the more immediate future, 10 of the 17 top-priority islands on which rats reside appear to be within or around the current achievements of a ground-based eradication in terms of size and human population. A black rat eradication programme has since begun on two of these (uninhabited) priority islands in the Shiant Isles.

Most current prioritisation methods include an estimation of eradication cost. As a general rule, costs tend to increase with island size (Howald et al. 2007; Donlan et al. 2015), but Holmes et al. (2015) highlighted the need for better reporting of the main costs associated with eradications to help future decision-making. High costs of eradication projects need not necessarily pose an impediment to successful implementation, as targeted fundraising can meet the financial needs for even an expensive operation (e.g. the rodent eradication on South Georgia £7.5 million (UK Parliament 2012)). Given that eradications are one of the most efficient conservation interventions (Donlan et al. 2015; Jones et al. 2016), we argue that a strategic prioritisation should identify the islands with the greatest potential biodiversity benefit regardless of the financial cost. This approach therefore entails the risk that some of the islands identified as high priority may require exceptionally expensive eradications, for example because they are large or inhabited by a significant human population. We implicitly accept that the cumulative benefit of restoration of several low-cost interventions on a suite of islands may be greater than one larger or more complex project. Costing eradication projects can be complex, and there is a limited amount of data for some IAV groups (Brooke et al. 2007; Donlan and Wilcox 2007; Martins et al. 2006), but estimates can be achieved based on the method outlined in Brooke et al. (2007). An 'action portfolio' approach, which allows the costs and benefits of eradicating any possible combination of IAVs to be calculated (Helmstedt et al. 2016) could also be used, but this requires quantitative data about species interactions, extinction risk and eradication success probabilities, which are frequently unavailable for a large number of islands.

Many UK islands of conservation importance remain free of IAVs such as rats, cats and mustelids. Currently, most UK islands have inadequate levels of biosecurity in place to prevent (re)invasion by IAVs and invasions continue to occur. Our brown rat biosecurity analysis creates a priority list for biosecurity measures by assessing the likely damage to benefit species if brown rats were to establish on an island. Although many of the priority biosecurity sites are not easily accessible, to consider them low risk would be erroneous. The wrecking of *The Spinningdale* on St. Kilda in 2008 illustrates that biosecurity and rapid response plans are required for even the most remote or seldom-visited islands. In this instance, a team was able to respond within 48 h of the incident, but this level of preparedness is unusual for the UK.

Our analysis has focussed on priorities at a UK scale and highlights the importance of Scottish islands in relation to potential IAV eradications and Scotland, Wales and the islands off the northeast coast of England for rodent biosecurity. We are aware, however, that much conservation decision-making and action is conducted at a country scale and that islands elsewhere may be of considerable interest. Supporting Information S5 enables users to assess the relative importance of any island, and priority lists can be created for the individual countries and Crown Dependencies that make up the UK and different subsets of benefit species/IAVs.

Acknowledgements The authors would like to acknowledge everyone who helped construct the benefit and IAV databases; from those carrying out surveys, submitting ad hoc records, writing ecological atlases or working on national recording schemes to local experts providing information directly to the project. J. Russell, J. Millett, N. Holmes and J. Dawson provided valuable advice at different stages of the project.

References

Abbott I (2000) Improving the conservation of threatened and rare mammal species through translocation to islands: case study Western Australia. Biol Conserv 93:195–201

Arntzen JW, Wilkinson JW, Butôt R (2014) A new vertebrate species native to the British isles: Bufo spinosus Daudin, 1803 in Jersey. The Herpetological Journal 24:209–216

Balmer DE et al (2013) Bird atlas 2007–11: the breeding and wintering birds of Britain and Ireland. BTO, Thetford

BirdLife International (2004) Birds in Europe: population estimates, trends and conservation status. Cambridge

BirdLife International (2015) European red list of birds. Office for Official Publications of the European Communities, Luxembourg

Booker H, Price D (2014) Manx shearwater recovery on Lundy: population and distribution change from 2001 to 2013. Journal of the Lundy Field Society 4:105–116

BRIG (2007) Report on the species and habitat review: report to the UK standing committee June 2007. Biodiversity Reporting and Information Group, Peterborough

Brooke ML, Hilton G, Martins T (2007) Prioritizing the world's islands for vertebrate-eradication programmes. Anim Conserv 10:380–390

Buxton RT, Jones C, Moller H, Towns DR (2014) Drivers of seabird population recovery on New Zealand islands after predator eradication. Conserv Biol 28:333–344

Clout MN, Russell JC (2008) The invasion ecology of mammals: a global perspective. Wildl Res 35:180–184

Courchamp F, Chapuis J-L, Pascal M (2003) Mammal invaders on islands: impact, control and control impact. Biol Rev 78:347–383

Dawson J et al (2015) Prioritizing islands for the eradication of invasive vertebrates in the United Kingdom overseas territories. Conserv Biol 29:143–153

DIISE (2016) The database of island invasive species eradications, developed by island conservation, coastal conservation action laboratory UCSC, IUCN SSC invasive species specialist group. University of Auckland and Landcare Research New Zealand, Auckland http://diise.islandconservation.org

Donlan C, Wilcox C (2007) Complexities of costing eradications. Anim Conserv 10:154–156

Donlan CJ, Luque GM, Wilcox C (2015) Maximizing return on Investment for Island Restoration and Species Conservation. Conserv Lett 8:171–179

Eaton M et al (2015) Birds of conservation concern 4: the population status of birds in the UK, Channel Islands and Isle of Man. British Birds 108:708–746

Ecosure (2009) Prioritisation of high conservation status of offshore islands. Report to the Australian Government Department of the Environment, Water, Heritage and the Arts. Ecosure, Cairns, Queensland

Edgar P (2010) The amphibians and reptiles of the UK Overseas Territories, Crown Dependencies and Sovereign Base Areas: Species inventory and overview of conservation and research priorities. Final Report to the Amphibian and Reptile Conservation, Boscombe, UK

Fraser EJ, Lambin X, McDonald RA, Redpath SM (2015) Stoat (Mustela erminea) on the Orkney Islands – assessing risks to native species vol No. 871. Scottish Natural Heritage Commissioned Report

Game ET, Kareiva P, Possingham HP (2013) Six common mistakes in conservation priority setting. Conserv Biol 27:480–485

Genovesi P, Carnevali L (2011) Invasive alien species on European islands: eradications and priorities for future work. In: Veitch CR, Clout MN, Towns DR (eds) Island invasives: eradication and management. IUCN, (International Union for Conservation of Nature), Gland, Switzerland, pp 56–62

Glen AS et al (2013) Eradicating multiple invasive species on inhabited islands: the next big step in island restoration? Biol Invasions 15: 2589–2603

Harris S, Yalden DWY (2008) Mammals of the British Isles: handbook. Mammal society

Harris S, Morris P, Wray S, Yalden D (1995) A review of British mammals: population estimates and conservation status of British mammals other than cetaceans. Joint Nature Conservation Committee, Peterborough, UK, p 52

Harris D, Gregory SD, Bull L, Courchamp F (2012) Island prioritization for invasive rodent eradications with an emphasis on reinvasion risk. Biol Invasions 14:1251–1263

Heaney V, St Pierre P (2015) The status of seabirds breeding in the Isles of Scilly 2015. Unpublished Royal Society for the Protection of Birds report

Heaney V, Lock L, St Pierre P, Brown A (2008) Important bird areas: breeding seabirds on the isles of Scilly. British Birds 101:418–438

Heath M, Evans M, Hoccom D, Payne A, Peet N, Birdlife International C (2000) Important bird areas in Europe priority sites for conservation. v. 1: Northern Europa. v. 2: Southern Europe BirdLife Conservation Series (RU)

Helmstedt KJ, Shaw JD, Bode M, Terauds A, Springer K, Robinson SA, Possingham HP (2016) Prioritizing eradication actions on islands: it's not all or nothing. J Appl Ecol. doi:10.1111/1365-2664.12599

Hervías S et al (2013) Studying the effects of multiple invasive mammals on Cory's shearwater nest survival. Biol Invasions 15:143–155

Holmes N, Campbell K, Keitt B, Griffiths R, Beek J, Donlan C, Broome K (2015) Reporting costs for invasive vertebrate eradications. Biol Invasions 17:2913–2925

Howald G et al (2007) Invasive rodent eradication on islands. Conserv Biol 21:1258–1268

Iucnredlistorg (2016) Iucnredlistorg. Retrieved 30 June 2016, from http://www.iucnredlist.org

Jones HP, et al. (2016) Invasive-mammal eradication on islands results in substantial conservation gains. Proceedings of the National Academy of Sciences. 113.15:4033–4038

Martins T, Brooke ML, Hilton G, Farnsworth S, Gould J, Pain D (2006) Costing eradications of alien mammals from islands. Anim Conserv 9:439–444

Mitchell PI, Newton SF, Ratcliffe N, Dunn TE (2004) Seabird populations of Britain and Ireland. T and AD Poyser, London

Morgan G (2012) The bird populations of Ramsey and Grassholm. British Birds 105:716–732

Mulville J (2010) Red deer on Scottish islands. In: Sykes NJ (ed) Extinctions and invasions: a social history of British fauna. Windgather Press, Oxbow Books, Oxford, pp 43–50

Ogden J, Gilbert J (2009) Prospects for the eradication of rats from a large inhabited island: community based ecosystem studies on great Barrier Island, New Zealand. Biol Invasions 11(7):1705–1717

Onsgovuk (2016) Onsgovuk. Retrieved 30 June, 2016, from https://www.ons.gov.uk/census/2011census/2011ukcensuses

Oppel S, Beaven BM, Bolton M, Vickery J, Bodey TW (2011) Eradication of invasive mammals on islands inhabited by humans and domestic animals. Conserv Biol 25:232–240

R Development Core Team (2015) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria ISBN 3–900051–07–0, URL: http://www. R-project. org

Ratcliffe N, Mitchell I, Varnham K, Verboven N, Higson P (2009) How to prioritize rat management for the benefit of petrels: a case study of the UK, Channel Islands and Isle of Man. Ibis 151:699–708

Roy SS, Chauvenet AL, Robertson PA (2015) Removal of American mink (Neovison vison) from the Uists, outer Hebrides, Scotland. Biol Invasions 17(10):2811–2820

Ruscoe WA et al (2011) Unexpected consequences of control: competitive vs. predator release in a four-species assemblage of invasive mammals. Ecol Lett 14:1035–1042

Russell JC, Clout MN (2004) Modelling the distribution and interaction of introduced rodents on New Zealand offshore islands. Glob Ecol Biogeogr 13:497–507

Russell JC, Beaven BM, MacKay JW, Towns DR, Clout MN (2008a) Testing island biosecurity systems for invasive rats. Wildl Res 35: 215–221

Russell JC, Towns DR, Clout MN (2008b) Review of rat invasion biology: implications for island biosecurity. Science for conservation

Scotlandscensusgovuk (2016) Scotlandscensusgovuk. Retrieved 30 June, 2016, from http://www.scotlandscensus.gov.uk/census-results

Serjeantson D (1990) The introduction of mammals to the outer Hebrides and the role of boats in stock management. Anthropozoologica:7–18

Stoneman J, Zonfrillo B (2005) The eradication of brown rats from Handa Island, Sutherland. Scottish Birds 25:17

Tabak MA, Poncet S, Passfield K, Martinez del Rio CC (2015) Modeling the distribution of Norway rats (Rattus norvegicus) on offshore islands in the Falkland Islands. NeoBiota 24:33–48

UK Parliamentuk (2012). Parliamentuk. Retrieved 23 August, 2016, from http://www.publications.parliament.uk/pa/cm201314/cmselect/cmenvaud/332/332vw05.htm

Veale A (2013) Observations of stoats (Mustela erminea) swimming. New Zealand Journal of Zoology 40:166–169