PERSPECTIVE

Special Issue on Invasive Mammal Species

The challenges of long-term invasive mammal management: lessons from the UK

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ABSTRACT

We consider the motivations, strategies and costs involved in invasive mammal management undertaken in the UK. Widespread established invasive mammals require long-term management to limit damage or spread, but ongoing management is costly and complex. Long-term management is most effective where it is applied at a landscape scale, but this requires overarching co-ordination between multiple stakeholders. Five challenges for successful long-term management of invasive mammal species are identified as: defining landscape scale strategies, management co-ordination, stakeholder and community engagement, sustainable funding and evidence requirements. We make recommendations on the supportive infrastructure needed for effective landscape-scale management of invasive mammals to fulfil long-term conservation aims, as follows. 1. There is a need for evidence-based Invasive Species Action Plans to provide strategy for the long-term ongoing management of prioritised species at appropriate scales. 2. Where possible, multispecies approaches to invasive species management should be adopted. 3. Trusted leadership should be identified to take ownership of Action Plans and provide an overarching co-ordination to bring individuals, organisations and funders together. 4. Support for a centralised hub for training, data and knowledge flows will greatly improve scientific outcomes through a searchable evidence base and best practise and knowledge sharing.

Key words: impact, invasive species, landscape, mink, squirrel, stakeholder, United Kingdom

Running Head: Long-term landscape-scale invasive management

Received: 25 April 2019

Accepted: 6 November 2019

Editor: DR

Special Issue Guest Editor: Sandro Bertolino

INTRODUCTION

Invasive species are identifiable by their environmental, economic and societal impacts. Throughout the globe, invasive mammals cause substantial biodiversity impacts, including via predation of native species (Holmes et al. 2019) and disruption to native ecosystems. In the UK, some invasive mammals are so widespread that they are more abundant than native species (Mathews et al. 2018) and have significant ecosystem impacts. The most notable and abundant invasive mammal species in the UK are four deer species (Muntjac *Muntiacus reevesi*, Chinese water deer *Hydropotes inermis*, sika deer *Cervus nippon* and fallow deer *Dama dama*), the American mink *Neovison vison,* and the grey squirrel *Sciurus carolinensis.* All six species have caused the widespread alteration of ecosystems through grazing pressure or serious declines in native species. Mink are responsible for the collapse of populations of water voles *Arvicola amphibius*, terns *Sterna hirundo* and gulls *Laridae* (Craik 1997), and grey squirrels have caused the disappearance of the red squirrel *Sciurus vulgaris* in much of England and Wales. Damage from deer and squirrels can nullify economic returns from forestry, with profound long-term consequences for England's rural areas. Without some management, the damage and impacts would remain unmitigated.

International targets and policy commitments to manage invasive species such as the Convention for Biological Diversity include commitments to "introduce measures that prevent the introduction and significantly reduce the impacts of [invasive alien species], and control or eradicate priority species" (Convention for Biological Diversity 2014). National strategies for managing the threat of invasive species focus on strengthening biosecurity approaches to prevent new species from entering and, where they do appear, producing contingency plans to ensure their removal before populations can become established. In the UK, there are contingency plans for the removal of newly established invasive mammal species based on the European Union regulation; recent examples include the removal of a racoon *Procyon lotor* in 2016 and two coatimundi *Nasau nasua* in 2018. While eradication of all invasive mammals would remove their impacts, most are so widespread over huge landscapes, that eradication feasibility is limited by cost and practicalities (Booy et al. 2017). When prioritising invasive species for control or eradication, widespread mammal populations are often given low priority in the UK.

Managing widespread invasive species on the UK mainland involves ongoing control of local populations by landowning interests to limit local economic damage (such as deer), or control undertaken by stakeholders in the same way as the pest management of native or naturalised species. However, some invasive mammals also cause significant damage to wider biodiversity assets, warranting the involvement of multiple stakeholders (including conservation groups and broader public groups) in the ongoing management of these species.

Invasive mammal control projects that do not have eradication as their ultimate objective face multiple challenges. The objectives of ongoing control are often ill-defined, but they generally aim to maintain areas free of species' impacts. Achieving this invariably has significant ongoing costs and

requires co-ordination of management efforts over sufficiently large areas to minimise the rate of reinvasion from the periphery. The landscapes invaded by established species are large and can pose challenges for managing, often highly dispersive, invasive mammals. Such landscapes involve multiple stakeholders who have differing priorities around the need for and type of management. This means different groups may be working separately on the same, or different but similarly problematic, species with varying management objectives.

The benefit of ongoing control can be limited if it is performed on a small scale and requires continued effort and resources. The co-ordination of such efforts across larger landscapes can achieve enormous benefits. Recognition of this by the New Zealand government has led to an ambitious programme (Predator Free NZ 2050), which aims to remove eight species of non-native mammals from the entire country by 2050 (Russell et al. 2015). Such a level of ambition, and matching financial and community support for ongoing invasive species management as part of the biosecurity agenda, is currently lacking in the UK (Environmental Audit Committee 2019).

MANAGING WIDESPREAD INVASIVE MAMMALS IN THE UK

The principles required to achieve species eradication have been well documented (Bomford & O'Brien 1995) and a framework to assess eradication feasibility has been established (Booy et al. 2017). The majority of documented invasive mammal eradications are from oceanic islands and 57% involved removing rodents through poisoning (Jones et al 2016), which is not feasible on larger landmasses where poison may threaten native or domestic species. Larger mammals are most often controlled through trapping or shooting, but the logistics and manpower required are significant and the process can be protracted. There have been documented attempts to eradicate five invasive mammals from mainland UK since the 1930s (Table 1). These programmes have been instigated and co-ordinated by government agencies, and management has typically been undertaken by employed staff rather than volunteers. Eradications of muskrat *Ondatra zibethicus*, coypu *Myocastor coypus* and Himalayan porcupine *Hystrix brachyuran* were implemented to prevent potential economic losses from agricultural damage. These were among the largest successful mammal eradications worldwide, but required a substantial effort over many years to achieve (Robertson et al. 2017).

There are currently 12 invasive mammal species being managed across mainland UK (Table 2), and all are too widespread for eradication to be a feasible management objective. Instead, long-term management objectives encompass limiting spread, reducing densities to limit damage or maintaining areas clear of the species. Within defined areas, different control strategies are implemented in response to the management objectives (Fig. 1). Where densities are high, intensive control can be used to reduce impacts to within tolerable thresholds. Where densities and impacts of species are within a tolerable range, routine control is needed to limit density and minimise impacts. At densities lower than the impact threshold, monitoring and surveillance with targeted action can prevent impacts or allow spatial expansion of the protected area.

Specifying what density thresholds are tolerable is a socio-ecological question involving consideration of the resilience of native species to invasive species, the economic costs of damage, and the costs of the management required to maintain the density below the threshold. Such costs typically rise non-linearly as density decreases (Hone et al. 2017). Furthermore, the ability of native species and ecosystem functions to be maintained in the presence of invasive mammals is highly variable. Different species and economic activities have different density-impact functions on native biota (Norbury et al. 2015).

Three high-profile projects in the UK have recently demonstrated the potential and ambition for greater levels of co-ordinated control, and have convinced funders that this action has sufficient

131 societal benefits to warrant financing over 3-4 years (see Box). The species being managed,
132 American mink and grey squirrel, are widespread with significant biodiversity impacts. These funded
133 projects have given consideration and proposed plausible solutions to the challenges known to
134 confront such open-ended management schemes. However, in contrast with past eradication
135 programmes, these projects are co-ordinated by wildlife charities, not by national government staff,
136 and action is undertaken by a mixture of paid staff, volunteers and community groups (Table 2).
137 Despite having long-term aims, funding is time-limited and projects cannot continue without
138 alternative sustainable resourcing.

139 Here we argue that landscape-scale, co-ordinated approaches to the management of established
140 invasive mammals are necessary, to improve the success rates and cost-effectiveness of current
141 approaches. In reviewing the current landscape-scale invasive mammal management programmes in
142 the UK, we outline five challenges that need to be addressed to improve long-term invasive species
143 management.

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145 **Table 1.** Known co-ordinated management approaches of invasive mammal populations in the UK. NGO = non-government organisation.

Management	Species	Population managed	Co-ordination of control	References
National eradication				
	Muskrat *Ondatra zibethicus*	Successful eradication of 4388 individuals by trapping in Scotland, Ireland, Surrey, Shropshire and Sussex in the 1930s.	Government staff	Warwick (1934, 1940), Sheail (1988), Gosling & Baker (1989)
	Coypu *Myocastor coypus*	Successful removal of 34822 animals from 19210 km^2 in East Anglia, 1980s	Government staff	Gosling & Baker (1989)
	American mink *Neovison vison*	Failed attempt at national eradication by trapping in 1960s	Government staff	Thompson (1971), Sheail (2004)
	Edible dormouse *Glis glis*	Failed attempt to eradicate original population	Landowners	Vesey-Fitzgerald (1936)
	Himalayan porcupine *Hystrix brachyura*	Successful eradication of 6 individuals from SW England in 1970s	Government staff	Baker (2010)
Island eradication				
	American mink *Neovison vison*	Ongoing eradication attempt across 3461 km^2 in Outer Hebrides, Scotland since 2000s	Government staff	Lambin (2014), Roy et al. (2015)
	Grey squirrel *Sciurus carolinensis*	Successful eradication removed 6397 from 710 km^2 on Anglesey, North Wales in 2000s	NGO staff	Schuchert et al. (2014), Shuttleworth et al. (2015)
	Black rat *Rattus rattus*	Successful eradications from islands up to 4.5 km^2: Lundy, SW England 2004, Shiants, NW Scotland 2018	NGO staff	Appleton et al. (2006), RSPB (2018)
	Brown rat *Rattus norvegicus*	Successful eradication from islands up to 4.5 km^2: Lundy, SW England 2004, Ailsa Craig, W Scotland 1992, Cardigan SW Wales 1968, Puffin Island, Wales 1998, Ramsey SW Wales 2000, Handa, NW Scotland 1997, Canna W Scotland 2008, Saint Agnes, Gugh, Annet, Isles of Scilly 2016.	NGO staff	Appleton et al. (2006), Zonfrillo (2001), Dryfed Wildlife Trust (1994), Johnstone et al. (2005), Bell et al. (2011), DIISE (2015)
	Feral goat *Capra hircus*	Failed attempt to eradicate from Holy Island, W. Scotland in 1963	NGO staff	DIISE (2015)

	Rabbit *Oryctolagus cuniculus*	Successful removal from Eynhallow, Orkney, N Scotland 1955, Scolt Head, E England 1955 and Fidra, E Scotland 1961	NGO staff	DIISE (2015)
Regional population removal				
	American mink *Neovison vison*	Ongoing maintenance of cleared area (29000 km^2) in Scottish Highlands	NGO staff and volunteers	Bryce et al. (2011), Melero et al. (2018), Lambin at al. (2018)
	Grey squirrel *Sciurus carolinensis*	Unsuccessful campaign to keep < 46km^2 Thetford Forest, East Anglia, clear, 2209 animals removed.	Volunteers	Gurnell & Steele (2002)
Bounty schemes (1950s)				
	Coypu *Myocastor coypus*	Government support for local control groups prior to eradication	Landowners	Sheail (2003)
	Grey squirrel *Sciurus carolinensis*	Nationwide campaign removed one million animals 1953-58	Landowners	Sheail (2004)
	Rabbit *Oryctolagus cuniculus*	Government support for local clearance groups	Landowners	Sheail (1991)

Table 2. Current on-going management of widespread invasive mammals where objectives are to limit spread, reduce densities to limit damage or maintain areas clear of the species. Estimated UK populations from Mathews et al. (2018) shown with 95% confidence intervals. NGO = non-government organisation. * Brown Hare while introduced is also regarded as a naturalised and is a Biodiversity Action Plan priority species, however is it still controlled for damage to agricultural crops.

Species	estimated UK population	Co-ordination of control
Reeves muntjac *Muntiacus reevesi*	128,000 (115,000 -147,000)	Landowners
American mink *Neovison vison*	~122,000	Landowners, NGOs and local volunteer communities
Grey squirrel *Sciurus carolinensis*	2,700,000 (1,340,000 - 3,790,000)	Landowners, NGOs and local volunteer communities
Edible dormouse *Glis glis*	23000 (9,800 - 82,000)	Landowners and home-owners
Brown rat *Rattus norvegicus*	~7,070,000	Landowners and home-owners
Sika deer *Cervus nippon*	103,000 (27,000 - 266,000)	Landowners
Fallow deer *Dama dama*	264,000 (194,000 - 343,000)	Landowners

Chinese water deer *Hydropotes inermis*	3600 (200 - 43,000)	Landowners
House mouse *Mus musculus*	~5,203,000	Landowners and home-owners
Brown hare* *Lepus europaeus*	579,000 (427,000 - 1,990,000)	Landowners
Feral goat *Capra hircus*	Discrete Populations	Landowners
Rabbit *Oryctolagus cuniculus*	~3,600,000	Landowners

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CHALLENGE 1: DEFINING LANDSCAPE-SCALE MANAGEMENT STRATEGIES

Removal of widespread and highly dispersive invasive mammals from small areas can be inefficient or futile, as recolonisation from the periphery is inevitable and requires constant monitoring and management (Lawton & Rochford 2007). Funding for repeated invasive species control across the same geographic areas year on year is difficult to obtain, yet often some action is necessary to mitigate damaging impacts. Management strategies that encompass a broader geographic scale are more cost-effective (Robertson et al. 2017), can take account of natural boundaries of suitable habitats (Goldstein et al. 2016) and geographic barriers (such as elevation or coastlines), and can help reduce the likelihood or frequency of reinvasion of a cleared area (Robertson et al. 2018). Defining the appropriate ecologically meaningful scale depends on the species and its interaction with the landscape. Habitat quality can be used as an indicator of suitability, and therefore likelihood of colonisation or key dispersal routes. Targeted control across a landscape focuses on intercepting dispersing mammals or using areas of highly suitable habitat as 'ecological traps' (Melero et al. 2018). By integrating knowledge of the ecology of the target species and managing at a sufficient scale, a spatial strategy can be employed to increase the efficiency of control efforts and maximise protection of biodiversity interests across whole landscapes.

CHALLENGE 2: CO-ORDINATION OF MANAGEMENT

Since 2006, UK wide invasive species policy is set out in the Non-Native Species Framework, delivered by a Secretariat. The Secretariat, however, only consists of a few staff, and their primary role is to provide advice and support for activities such as risk assessment; they are not responsible for decision-making and there is no provision for managing species on the ground. The GB Non-Native Species Framework promotes long-term management and local action through Invasive Species Action Plans and regional Local Action Groups. Much of the current Local Action Group network is focussed on weeds and riparian systems, but work is geared towards co-ordinated action and sharing of best practice. There are currently no Invasive Species Action Plans for mammals; developing these could be the first step towards building co-ordinated approaches. However, realisation of these plans would require co-ordination between different projects, and agreement as to how each project contributes to the aims of the action plan.

The GB Non-Native Species Framework recognises that the development and implementation of a GB strategy should build on existing capacity and expertise to achieve effective co-ordination of existing management activities. Some statutory bodies and organisations are responsible for invasive species control on land they own or manage. However, they have no responsibility for co-ordinating action at a national scale. Some species-specific initiatives and networks exist with varying objectives and structures. The Deer Initiative, a broad partnership of organisations with interests in deer management, all of whom are signatory to an accord, and whose operations are delivered by a small team of employees working to achieve consensus among landholders (www.thedeerinitiative.co.uk), has in part been a victim of its own success. Improvements to woodland condition (a common objective across landscapes) are evident in areas where the Deer Initiative has been facilitating collaboration and co-ordination of stakeholder action at landscape scales for several years. However, changes to funding streams and the transferability of its activities to its partner organisations mean that the Deer Initiative will close from March 2020. Whether metrics of deer management performance continue to indicate success in the absence of the Deer Initiative remains to be seen. The UK Squirrel Accord is a partnership between a number of agencies and organisations with an interest in grey squirrel management (http://squirrelaccord.uk/); the Northern Ireland Squirrel Forum is a similar partnership of statutory and non-statutory organisations in Northern Ireland.

These partnerships do not provide funding for control, and currently do little to co-ordinate and guide management for a common objective. A management co-ordination role, e.g. Saving Scotland's Red Squirrels (see Box), should include data sharing and directing management efforts to high priority areas as well as facilitating shared best practise, equipment and centralised training.

CHALLENGE 3: STAKEHOLDER CONTRIBUTIONS AND COMMUNITY ENGAGEMENT

There is increasing recognition of the importance of stakeholder involvement in research and management of invasive species and that increased interaction between policy-makers, academics and practitioners can improve management approaches (Pages et al. 2019; Shackleton et al. 2019). Landowner support is crucial to a landscape-scale approach to invasive mammal management, but in some places access to land can be a barrier to ensuring comprehensive coverage. Lack of landowner commitment may be due to other priorities, limited resources or because of conflicting views or the fear of public opposition to controversial management of charismatic species (Niemiec et al. 2019). Where landowners are supportive of the management objectives of invasive species control, access requests to trap or shoot can be refused on the grounds of health and safety concerns or insurance requirements. Demonstration of training and adherence to standards can alleviate these concerns (e.g. professionally accredited courses), and many local volunteer groups fundraise to cover personal and liability insurance and training needs of their members. Having a landscape-scale strategy can help to achieve buy-in from neighbouring landowners. Awareness raising, relationship development and advocacy are important for knowledge exchange and dissemination, and for gaining trust and support between stakeholders of invasive mammal control campaigns. However, short funding timeframes do not provide sufficient time to allow these relationships to be built. Co-ordinating partnerships (see Box) ensures standardised training and accreditation, brings financial benefits of scale, and are a good way to ensure appropriate methods and high welfare standards are maintained.

In the UK, there are precedents for small volunteer-based groups leading conservation efforts. For example, there are >30 registered local red squirrel conservation groups working throughout the NE of England, many facing similar resourcing challenges. Researchers have identified multiple drivers for environmental volunteering, including pro-social motivations such as contributing to their community, personal reasons such as increasing social interactions or developing skills, a general ethic of care towards the environment and/or a particular attachment to the place or issue concerned (Measham & Barnett 2008). Volunteers are involved in invasive species management in several ways, including monitoring, fundraising, public engagement and direct assistance with control. Volunteer effort can also vary from the relatively simple and infrequent to more challenging and time-consuming roles, such as co-ordinating a volunteer group or contributing specialist skills to a management scheme. Although there is often a diversity of roles available to volunteers, the most popular activities may be oversubscribed (e.g. monitoring red squirrels in areas where they are found), while more mundane or challenging tasks can be difficult to recruit to (e.g. few people are willing to kill animals or to gain the appropriate training).

Despite the benefits of recruiting engaged, skilled and motivated volunteers, heavy reliance on volunteer effort can nevertheless pose challenges for invasive species management projects. First, these initiatives often rely on the ongoing engagement of people who may be time-poor, and whose other commitments may understandably come before their voluntary work. Second, volunteer retention can be challenging unless volunteers see rapid results or feel their continued efforts are making a difference. Unfortunately, the timescales over which landscape-scale management

strategies make observable change are long, and even where progress is being made this may not be immediately apparent to volunteers. Volunteering as an extension of existing work may be one way to ensure long-term participation; for example, fisheries employees have additionally volunteered on mink trapping programmes over extended periods, as the volunteering duties fit reasonably well with the objectives and schedules of their daily work (Lambin et al.2018).

To fully engage stakeholder participation in landscape-scale control and to determine what management action is feasible, there is a need to combine the motivations and knowledge of the conservation and stakeholder community with academic understanding of both social and ecological environmental processes. This integration can be achieved with support and expertise from academic and non-governmental organisations (Reed 2008), but it requires co-ordination and sustained funding.

CHALLENGE 4: SUSTAINABLE FUNDING

Obtaining funding for repeated invasive species control in the same geographic areas year on year is difficult, yet action is necessary to mitigate damaging impacts. Where there is no co-ordination of long-term management, limited funding can unwittingly be spent resourcing the same infrastructure and project support needs, e.g. designing data collection platforms, and implementing training and public awareness-raising campaigns, often to the detriment of action on the ground. The lack of sustainable funding can also result in competition between organisations working on the same species, who may lose sight of the bigger picture and rarely work towards a common strategy.

The majority of funding for invasive mammal management projects is currently through EU LIFE, (https://ec.europa.eu/easme/en/life) and the National Lottery Heritage Fund (https://www.heritagefund.org.uk/), which typically finance projects over three to five years. These funders are increasingly looking for novel projects that engage with volunteers and local communities. This is a laudable approach, but there is concern that money is being detracted from direct action, leading to tensions over what takes priority when it comes to invasive mammal management. Funders rarely support follow-on projects, forcing the continual rebranding and formulation of project aims for what is essentially on-going control.

Funded co-ordinated action for long-term control at the UK governmental level is lacking, as widespread species are of low priority and funding is not committed to open-ended projects. Without central funding, maintaining ongoing control through phased projects is both challenging to achieve and damaging to project identity and retention of a workforce (Lambin et al. 2019). Alternative funding sources are needed to support the co-ordination of activities under a recognisable banner with a long-term commitment, such as the strategy of Saving Scotland's Red Squirrels. Access to alternative funding sources or incentives may result from Brexit or from Common Agricultural Policy reforms, but to achieve landscape-scale objectives, we need a better mechanism to support projects across species and between areas to achieve the best impact (Environmental Audit Committee 2019).

CHALLENGE 5: EVIDENCING PROGRESS AND BENEFITS

Data collation is essential to demonstrate the success of invasive mammal management, but also offers the opportunity for learning and sharing of knowledge gained. A key feature of scaling action across landscapes is the need to collate and share data at these larger scales, to record action and document progress (Lambin et al. 2018). These data may simply be mapping activity or may include more detailed records of surveillance effort, control action and biodiversity or economic gains that can be used to assess the impact of control efforts formally, and to plan future action (Harrington et al. 2020).

Evaluation of management effort is critical to securing public funding for grey squirrel control (Bryce & Tonkin2018). The Saving Scotland's Red Squirrels project (see Box) has launched a web-based community hub (https://scottishsquirrels.org.uk/) aimed at collecting evidence to support the project whilst providing an online resource for data recording and information. The aim of the hub is to connect interested members of the public, volunteers and landowners across a large country, and create a centralised location for the project's data and volunteer management. The hub accommodates activities for the public through reporting and viewing squirrel sightings, for registered volunteers through monitoring and trapping data, and for independent network groups to co-ordinate all their activities and data entry. The hub also allows volunteers to track their training, and record volunteer hours, and promotes Scotland-wide networking. While digital innovation is the way forward, there is a danger that, without co-ordination, different projects invest and design their own individual data-collecting mechanisms, making data sharing and comparison at a broad scale more challenging or impossible (Wilson et al. 2018). A recent Scottish Biodiversity Information Forum review of data recording recognised a need for a professional function that focuses on mobilising and collecting data, not just for invasive species, but across all aspects of conservation (Wilson et al. 2018). A co-ordinated approach may make it possible to harness data from consultancies, developers and private businesses who may be carrying out invasive species control in some areas yet do not feed into existing mechanisms.

Strategic management programmes use modelling approaches to improve efficiencies and the spatial deployment of effort (Melero et al. 2018). Landscape-scale models of habitat suitability and population dynamics can help prioritise management action. However, these approaches require understanding of species dispersal and habitat requirements to be able to predict where in the landscape species present the greatest risk, or knowledge of population parameters, such as survival and fecundity rates, to assess the level and type of management required to prevent further population growth (Ward et al. 2020).

Often, the optimal strategy for controlling or monitoring invasive species is not known at the outset and a degree of flexibility within the strategy is needed to allow learning about the system to be integrated into the management. Adaptive management approaches can improve the effectiveness of management, e.g. though comparison of observed impacts of different spatial or temporal trapping strategies with predictions from population models that include management (Bryce et al. 2011). The framework requires an agreed measurable objective (e.g. quanitified reduction in population density) and systematic monitoring of the management effectiveness to update understanding of the system and consequently refine the management action. To date, monitoring and adaptive management processes have been under-utilised in invasive species management (Richardson et al. 2020), but a common strategic approach could facilitate their uptake and improve the cost-efficiency of programmes (Will et al. 2014). Adaptive management can also be used to integrate multiple management approaches, such as the use of the latest technology and techniques. For example, automated remote traps (Jones et al. 2015) can reduce effort, as they do not need a manual check every day, and the use of conservation dogs can increase species detection.

CONCLUSIONS

Funding for invasive mammal species control in the UK has been decreasing steadily over the years, leading to competition between conservation-based organisations over funding to manage species in their own areas. Mammal control in the UK relies on the dedication of conservationists and landowners to reduce or eliminate the impacts of invasive species, but only large-scale efforts offer the chance of achieving sustainability. Working at ecologically relevant scales maximises the use of

landscape geography to manage potential reinvasion, and offers economies of scale to make best use of expertise and volunteering efforts. While there are inherent challenges in working at larger scales, co-ordination across landscapes, organisations, volunteers and species is feasible. If achieved, the potential benefits would be enormous and the potential for species eradications may become reality. Currently, we are faced with limited or short-term funding that inhibits project effectiveness, longevity and relationship building. Individual projects are often localised, species-specific, and reliant on the good will, motivation and skills of volunteers that also entail management and training transaction costs.

Joined-up approaches could facilitate a standardised way to collect data that will improve significantly the ability to compare scientific data, prioritise management actions, evidence impact and offer a mechanism to share knowledge and lessons learned. Co-ordination will also provide a centralised source of training in invasive species management to maintain high welfare standards and offer economies of scale, so that resources can be spent on actual management such as control activities. However, joining up organisations, stakeholders and volunteers across species and landscapes will require careful co-ordination to provide all the benefits of the large scale, whilst allowing for local contexts and characteristics. If we are to improve the chances of species and ecosystems under threat in the UK, it is time for relevant bodies to acknowledge the inefficiencies and challenges of current approaches, despite considerable efforts at local scales, and identify a sustainable pathway going forward for species management. With this in mind, we recommend the following principles as a benchmark for future discussions on joined-up thinking and action.

1. There is a need for evidence-based Invasive Species Action Plans to provide strategy for the long-term ongoing management of prioritised species at appropriate scales.
2. Where possible, multispecies approaches to invasive species management should be adopted.
3. Trusted leadership should be identified to take ownership of Action Plans and provide an overarching co-ordination to bring individuals, organisations and funders together.
4. Support for a centralised hub for training, data and knowledge flows will greatly improve scientific outcomes through a searchable evidence base and best practise and knowledge sharing.

ACKNOWLEDGEMENTS

We thank all participants at the Red Squirrels United panel discussion on landscape-scale management at the Mammal Society's Autumn Symposium on Invasive Species in November 2018.

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Box – management of American mink and grey squirrels in the UK

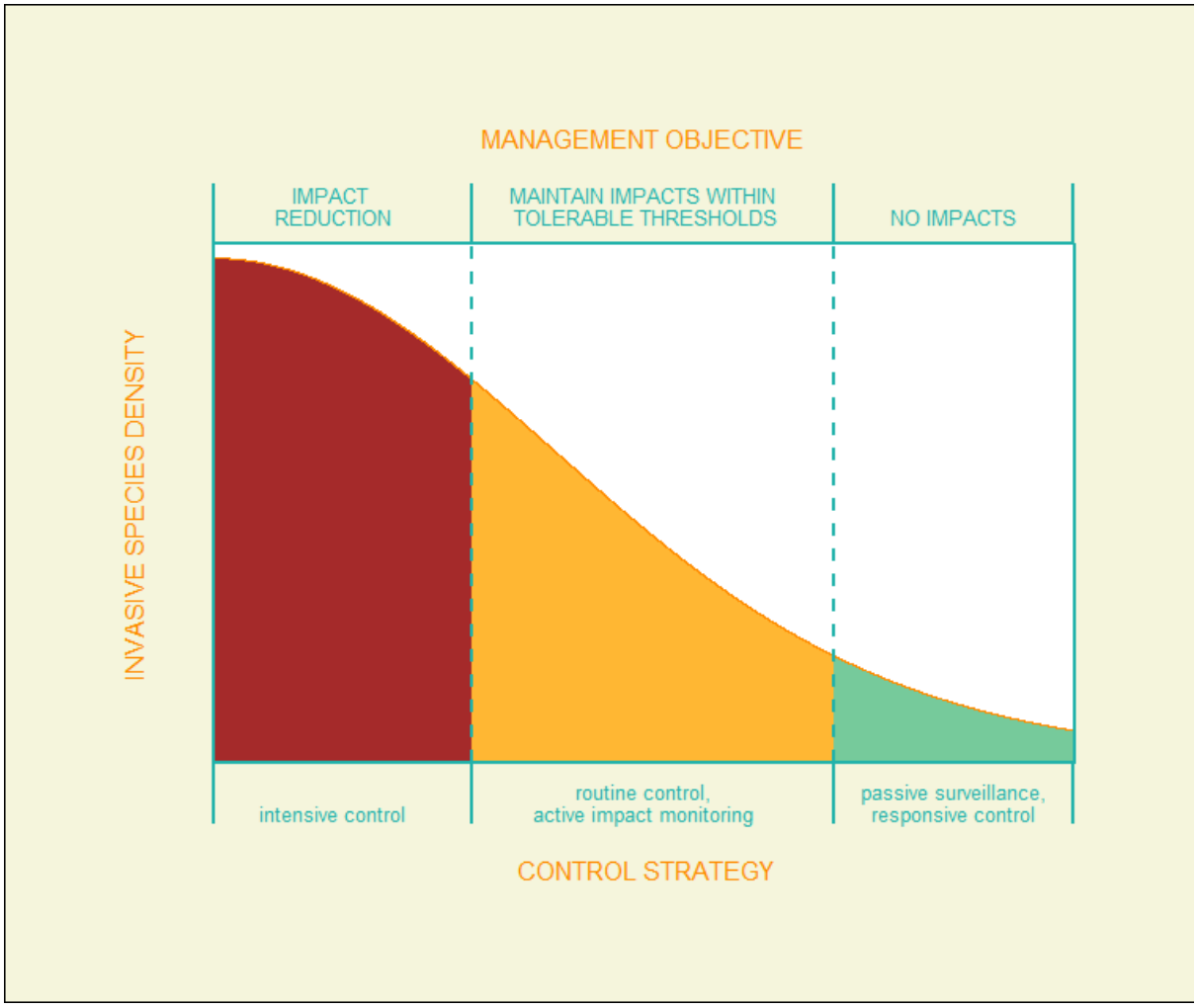
Red Squirrels United led a panel discussion at the Mammal Society Symposium Autumn Symposium on Invasive species in November 2018 on the future of invasive mammal management in the UK, with case studies of two invasive mammals - grey squirrel and mink – and their current funded management programmes in the UK. The absence of secured continuous funding for these projects for what are undoubtedly long-term conservation endeavours remains a major challenge to sustaining existing gains or expanding further.

Red Squirrels United. For many years, local red squirrel conservation groups had formed throughout the UK with little overarching co-ordination. Red Squirrels United is a four-year project funded through EU LIFE 14 (LIFE14/NAT/UK/000467) and the UK's National Lottery Heritage Fund from 2016-2020. Led by The Wildlife Trusts, the partnership consists of Northumberland Wildlife Trust, Red Squirrels Trust Wales, Ulster Wildlife, The Wildlife Trust for Lancashire, Manchester and North Merseyside, The Wildlife Trust of South and West Wales, Forest Research and Newcastle University. The Red Squirrels United project works in England, Wales and Northern Ireland and is the first project to bring together grey squirrel management for red squirrel conservation in different countries. The project aims are to support and encourage effective grey squirrel control effort, and to disseminate and evolve best-practice techniques, while protecting and expanding red squirrel populations.

Scottish Invasive Species Initiative. Long-term conservation efforts focussed on Scottish rivers started in 2004, later becoming the Scottish Mink Initiative (2010-2014) and then Scottish Invasive Species Initiative (2017-2021). The mink's northward spread has been stopped, and its ecological impact has been much reduced since 2010 in over 23000 km^2, 33% of the land mass of Scotland. The defining feature of the project is working with volunteers and local river trusts who have an economic stake in the health of river ecosystems. The initiative uses a formal adaptive management approach focussing on both ecological and socio-ecological issues (reviewed by Lambin et al. 2019). Since 2017, the initiative co-ordinates the management of multiple invasive species, having added five invasive plants to its remit alongside mink. Even though it was part funded by Scottish Natural Heritage, the project expanded, under multiple 3-4 year-long reincarnations with ever more ambitious objectives, over 15 years in the absence of long-term funding.

Saving Scotland's Red Squirrels. The Scottish Wildlife Trust lead a partnership (with Scottish Natural Heritage, Forestry Commission Scotland, RSPB Scotland, Scottish Land & Estates and the Red Squirrel Survival Trust) committed to red squirrel conservation through Saving Scotland's Red Squirrels over a 30-year timescale, with the intention to review the need to continue the work thereafter. The project is currently funded for five years by the National Lottery Heritage Fund (£2.46M 2017-2022). Saving Scotland's Red Squirrels is currently the largest project, geographically, tackling landscape-scale grey squirrel control for the conservation of red squirrels. The success of the project in stabilising and increasing red squirrel populations across strategically selected parts of Scotland has

led to the current phase of developing community action. This new phase aims to engage and empower local communities to take ownership of their local red squirrels, taking on vital project roles for red squirrel protection, creating a project legacy and assisting long-term sustainability.


MANAGEMENT OBJECTIVE
IMPACT REDUCTION
MAINTAIN IMPACTS WITHIN TOLERABLE THRESHOLDS
NO IMPACTS
INVASIVE SPECIES DENSITY
intensive control
routine control, active impact monitoring
passive surveillance, responsive control
CONTROL STRATEGY

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