Achieving large scale, long-term invasive American mink control in northern Scotland despite short term funding

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Abstract The American mink *(Neovison vison)* has invaded most of the United Kingdom following escapes from fur-farms over decades. Its escalating impact on riparian and coastal biodiversity, including seabirds and water voles, is well documented. Starting in north-east Scotland in 2004, long-term, multi-institution mink control efforts have harnessed the enthusiasm of volunteer conservationists to push back the mink invasion over a vast area. Rather than the outcome of a single project with secured long-term funding, this achievement resulted from four successive joined up projects each with short-term funding. The beginnings of the project (2004–2006), under the auspices of the north-east Scotland Biodiversity Partnership were small scale (30 km^2) and centred upon a lowland remnant water vole meta-population. Mink control efforts were scaled-up to 6,000 km^2 of mostly marginal mink habitat as part of the Cairngorms Water Vole Conservation Project (2006–2009) centred on the newly established Cairngorms National Park. The project, led by the University of Aberdeen, was funded by a charity, a UK Research council and Scottish Natural Heritage and involved the national park authority, and three local fisheries trusts. The approach was to deploy a "rolling carpet" of mink control based on the use of mink rafts operated by volunteers and that facilitated mink detection and removal. Substantial funding was then secured for a successor project, the Scottish Mink Initiative (2010–2014) involving, all previous partners plus 14 local fisheries trusts coordinated by the Rivers and Fisheries Trusts of Scotland. Mink were pushed back over a vast area (29,000 km^2) and their spread in coastal areas of north-west Scotland was countered. After a period with minimal bridge funding, coordinated mink control efforts resumed, thanks to the newly funded Scottish Invasive Species Initiative (2017–2021) seeking to extend the approach used with mink to other riparian invasives. Mink remain scarce or absent and water voles are recovering spectacularly. Coordinated mink control delivered tangible conservation benefits and improved understanding of the socio-ecological system despite the challenges of short-term funding.

Keywords: adaptive management, American mink, *Arvicola*, *Neovison vison*, participation, Scotland, water vole

INTRODUCTION

While there have been enormous achievements and improvements in the eradication of a small number of invasive mammalian species (brown (*Rattus norvegicus*) black (*R. rattus*) and Pacific (*R. exulans*) rats, house mice (*Mus musculus*), rabbits (*Oryctolagus cuniculus*), feral cats (*Felis catus*)), on islands of increasing size (DIISE, 2015), there has been comparatively little progress with efforts and guidelines on how to durably control invasive species in those areas where eradication is presently an unattainable goal. Yet, prevention has failed in many areas, such that focussing invasive management efforts exclusively on islands where eradication can be achieved leaves much valued biodiversity impacted by invasive species. Thus, when considering whether to expand resources to protect native biodiversity against the impact of invasive species, a key unknown is what, if anything short of eradication, can be achieved cost effectively and what management regimes might be both ecologically effective and sustainable over the long term.

Eradication can only be achieved where immigration can be prevented or managed (Bomford & O'Brien, 1995). Where this condition is not met, as is the case on continental mainland and large island areas, control of invasives must be the management objective. New Zealand's so-called 'mainland islands' are areas where intensive conservation adaptive and integrated pest management regimes are applied and outcomes are closely monitored (Saunders & Norton, 2001). They are adjacent to other areas where invasives are not managed to the same extent, hence subjected to immigration that, if not dealt with, could lead to recolonisation.

A key feature of mainland islands is that conservation management must be designed so as to last in perpetuity to ensure that the biodiversity and socio-community gains are not lost. It is therefore especially crucial that siting considers all features that may make a mainland island defensible. This may include topography (e.g. presence of peninsulas), ecological gradients or socio-economic interest of the local community that may affect their willingness to participate in ongoing management and adopt biosecurity measures and even the erection of conservation fences (Glen, et al., 2013). An unavoidable corollary of planning for the very long term, is the need for long-term funding commitments. This is crucial to negate the risk that ecosystem restoration will one day be undone should a lack of resources preclude a rapid and decisive reaction following incursion by invasives into a mainland island. In this respect, the fact that New Zealand's mainland islands are operated by the Department of Conservation, a government agency, provides a degree of continuity lacking elsewhere.

Owing to a lack of reported successful instances of control of invasive species in mainland areas, and to a few well publicised failures (e.g. Sheail, 2003; Santulli, et al., 2014), managers have little guidance as to the circumstances under which a mainland island approach might prove successful. Of particular interest is how complex institutional and funding environments need to be navigated when planning long term control of invasives. In the UK, for instance, protected areas are largely privately-owned; conservation legislation incentivises rather than mandates conservation management activities; a significant proportion of conservation action is initiated in a bottom up fashion by non-governmental organisation or local communities (often enabled by government agencies); and funding for projects rarely exceeds 3–5 years in duration.

In this paper, we present an account of the development of a mainland island invasive control effort that grew in spatial extent over 15 years from a localised community-led effort to operate on a vast scale (29,000 km^2) in the north of Scotland. It progressed from pilot, to demonstration

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and, eventually, mainstreaming stages without secured long-term funding but as an enduring partnership between academic researchers and practitioners under an adaptive management framework.

Invasive American mink threatening Ratty the water vole, a British cultural icon

The initial motivation for the project was the protection of the water vole (*Arvicola amphibius*), riparian rodents that used to be very abundant in Britain but that experienced a cumulative mean loss of occupied sites of 98.7% across all regions of England, Scotland, and Wales by 1998 from the 1939 baseline (Moorhouse, et al., 2015). Thus, the water vole was included amongst Species Action Plans and devolved Local Biodiversity Action Plans (LBAPs) when the UK Government launched those plans for the recovery of threatened species and habitats as part of the UK Biodiversity Action Plan in response to the Convention on Biological Diversity in 1994 (UK Biodiversity Partnership, 1995; JNCC, 2006). One of several suggested causes for the catastrophic decline of the water vole was the American mink *(Neovison vison)* that had invaded all but the north-westernmost corner of the UK following historical escapes from fur farms (Fraser, et al., 2015). Its overriding influence became clearer over time (Aars, et al., 2001; Moorhouse, et al., 2015). Accordingly, LBAPs included controlling mink, but little guidance or prescriptions on how this should be implemented were included.

SCALING UP MINK CONTROL: FOUR PHASES OF SPATIAL EXPANSION

Water voles in the catchment of the River Ythan (1995–2007): 100–644 km^2

Research into metapopulation processes by ecologists from the University of Aberdeen funded by the Natural Environment Research Council (NERC) (1995) identified a handful of highly fragmented remnant water vole populations in a 100 km^2 portion of an intensely farmed lowland area north of Aberdeen in NE Scotland (Telfer, et al., 2001) (Fig. 1). Structured surveys revealed that water voles had become regionally scarce or absent where they were once common (Lambin, et al., 1996; Lambin, et al., 1998; Lambin, et al., 2002). The intensively studied metapopulation network was gradually shrinking under the influence of American mink predation, causing the extinction of multiple adjacent colonies (Lambin, et al., 1996; Telfer, et al., 2001) (Table 1).

Fig. 1 Map of northern Scotland showing the five stages of expansion of successive mink control projects from a sub-catchment of the River Ythan (thick black line, numbered 1), the entire catchment of the River Ythan (Grey dashed lined, numbered 2), the Cairngorms National Park (thin black line, numbered 3), the area of the expanded Cairngorms project (dashed black line, numbered 4) and the area where the Scottish Mink Initiative operated (Continuous thick black line, numbered 5).

With funding secured by north-east Scotland's Local Biodiversity Action Plan group from Scottish Natural Heritage (SNH), the government agency tasked with promoting, caring for and improving Scotland's natural heritage (£145,000 over eight years, Fig. 2), the first stage of the northern Scotland control mink project was initiated in 2002. Its modest objective was to safeguard the remnant lowland water vole metapopulations by preventing further encroachment by mink. Initially, a member of staff from the local Ythan District Fishery Board, a statutory body empowered to protect, enhance and conserve Atlantic salmon and sea trout within the Ythan catchment, was employed on a part time basis to control mink (2002–2003). Subsequently, a full-time member of staff, employed by the University of Aberdeen (UoA), was appointed over five consecutive one-year contracts (2003–2007) as mink control activities were extended to the entire 644 km^2 area of the catchment of the river Ythan as evidence accumulated that it was possible to protect remnant water vole colonies from encroachment by mink (Fig. 1).

This early step was arguably an instance of last ditch conservation, focussed on safeguarding a fast-shrinking isolated remnant water vole metapopulation. It was nevertheless influential in shaping ways of working that became crucial as the project area was expanded 45-fold over the next 10 years.

Key features were:

i) Close links between research on water vole and mink population dynamics and conservation delivery;

ii) Systematic deployment of mink rafts that make it possible to detect the presence of mink and to target cage trapping to those sections of waterways where current mink presence is confirmed (Reynolds, et al., 2004);

iii) Involvement of local residents who were encouraged to volunteer to monitor and report the appearance of signs of mink on mink rafts in their neighbourhoods, allowing a single project officer to effectively control mink of an entire catchment through targeted trapping.

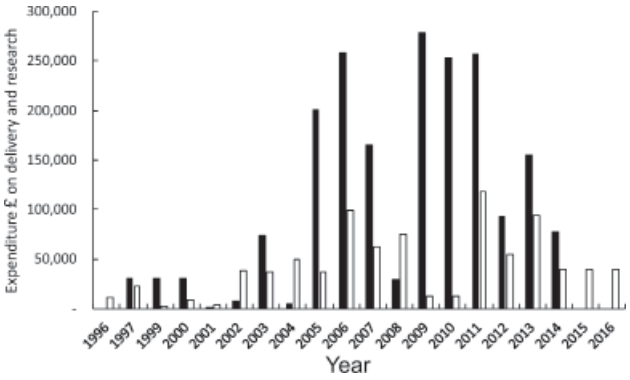

Fig. 2 Annualised expenditure of all projects relevant to water vole conservation and mink control broken down as funding for enabling or evaluating research (white bars) or conservation delivery (black bars).

iv) Partnership with organisations tasked with the management, conservation and enhancement of native freshwater fish and their environments in Scotland and increasingly involved in invasive species management.

In 2009, the river trust in the adjoining catchment of the River Deveron, emulated the project and obtained funding from SNH for an integrated package of invasives control, including American mink. The likely disappearance of the Ythan water vole population was averted, and this population is now thriving and extends across the entire lowland NE Aberdeenshire plain (W Morgan, E McHenry, X Lambin unpublished data).

The Cairngorms Water Vole Conservation Project (2007–2009): 5,500–10,570 km^2

Further surveys of water voles in the uplands of NE Scotland commissioned by SNH and research into metapopulation genetics processes by UoA (1998–2000) uncovered large water vole metapopulation networks in the area that was to become the Cairngorms National Park (CNP) in 2003 (Aars, et al., 2001; Lambin, et al., 1998; WildCRU, 2004) (Table 1). These populations, while in slow decline, had not yet been affected by the American mink invasion to the same extent as lowland populations, owing to the low density of alternative prey for mink in the uplands (Oliver, et al., 2009). They presented the opportunity to preserve functioning metapopulations and the associated ecosystem functions arising from the ecosystem engineering activities of water voles on upland riparian vegetation (Bryce, et al., 2013) as opposed to the more desperate task of rescuing critically endangered survivors.

The CNP encompasses a mountain massif, dominated by heather moorland where shooting of red deer (*Cervus elaphus*), red grouse (*Lagopus lagopus*) and fly fishing of salmon (*Salmo salar*) provide much needed income to the rural economy. In order to make these leisure activities possible, a large number of game keepers and fishing ghillies are employed to intensively manage heather moorland through rotational burning, killing predators of grouse and accompanying anglers. These individuals were recognised as a potential trained workforce that already culled ~ 60–70 mink annually in CNP, hence had the expertise and a professional interest in the issue. Their willingness to step up and coordinate hitherto patchy mink control was ascertained through consultation funded by the newly established CNP in 2004. Thus, we reasoned that the CNP was a potential defensible mainland island stronghold for water voles where mink control could be sustained in perpetuity.

Funding bids to the Tubney Charitable Trust, a charitable organisation for projects that conserve the natural environment in the UK, and to the NERC outlining the ambition to implement a formal active adaptive management approach to control American mink on the large scale of CNP (encompassing 5,500km^2, Fig. 1) were prepared. SNH had again committed match funding should either bid succeed. The Cairngorms National Park Authority (CNPA) and three river trusts managing important salmon rivers flowing from the Cairngorms (River Dee Trust, Spey Foundation and Deveron, Bogie & Isla Rivers Charitable Trust) were also formal partners committing in-kind staff time. Both bids were funded and substantial funding was in place for three years (2006–2009), facilitating the employment of three project officers and one postdoctoral research fellow by UoA.

A detailed account of the project's approach and achievements is given in Bryce, et al. (2011) and Oliver, et al. (2016) and a brief summary only is given here. The approach was to deploy mink rafts with an approximate spacing of 2 km in a 'rolling carpet' fashion to first remove mink from upland areas and subsequently expand coverage

Table 1 Sequence and main findings of research at the University of Aberdeen that enabled the next step of mink control efforts by characterising the system to be managed, that evaluated the achievements of mink control efforts or that provided a strategic evaluation of different ways or working.

Research Project	Years	Scope	Main finding	Funder
S. Telfer PhD	1996–1999	Enabling	Water voles metapopulation processes are disrupted by mink causing spatially correlated colony extinction	UK Research Council
J. Luque Larena Postdoc fellowship	2003–2004	Enabling	Cairngorms Mountains are invaded by mink owing to presence of rabbits in abandoned hill farms	European Union
A. Zalewski Postdoc fellowship	2005–2006	Enabling	Cairngorms Mountains are a partial obstacle to mink dispersal but mink circumvent hills and nevertheless spread	European Union
M.K. Oliver R. Bryce Postdoc fellowships	2006–2009	Evaluation	Strong lowland–highland source–sink dynamics and high mobility between catchments influencing capture rates	UK Research Council
E. Fraser PhD	2010–2013	Enabling	Mink spread in sparsely populated coastal areas is heavily constrained by topography and boat-based ecotourism operators are potential volunteers	SNH
M.K. Oliver Postdoc fellowship	2010	Evaluation	Mink control reduces captures to almost zero in three years. Mink dispersal large-scale (31 km for females), male biased, and links adjacent river catchments	UK Research Council
Y. Melero Postdoc fellowship	2011–2014	Evaluation	No evidence of mating failure at low density causing Allee effect but instead compensatory increase in fecundity at low density	European Union
E. McHenry PhD	2014–2018	Strategic	Doing more with less: optimising investment in detection and control	UK Charity
W. Morgan PhD	2014–2018	Evaluation	Patterns of recovery in water voles	UoA

downstream to remove mink from an increasingly large area, hence protecting the uplands with increasing depth; a version of the 'remove and protect model' with depth (Bell, et al., 2019). The systematic use of mink rafts was made possible by the work of 208 volunteers. We sought volunteers willing to adopt a mink raft and report to a project officer or trapper in their local community whether a mink was present. Only when fresh mink signs were detected was a cage live trap set, hence minimising the time wasted checking empty traps at least once every 24 hours as mandated by law. If a mink was caught (as occurred following 10–22% of detections according to season), it was humanely killed before the raft was returned to monitoring mode. The project officer played a crucial role in coordinating the efforts of volunteers, not all of whom were equipped or qualified to humanely despatch a mink. On detection of the presence of a mink by a volunteer, the full capabilities of the larger volunteer force could be called upon to effectively trap and despatch the mink.

Project officers sought permission to access the land and deploy a mink raft and then recruited local volunteers to operate the raft. Game-keepers who are licenced to carry fire-arms were partners of choice to adopt and operate mink rafts, although it proved difficult to dissuade them from their traditional practice of deploying traps irrespective of evidence of the presence of the focal species (Fig. 3). Two of three project officers had prior family or professional associations with the local game keeping community and this undoubtedly facilitated building constructive relationships. The adoption of rafts by local residents was key to allowing project officers to deploy further rafts downstream in the more biologically productive parts of the CNP and where landownership is more fragmented and residents with a wider diversity of professions live. Here, we adopted a functional approach to participation (Pretty, 1995) whereby local people were co-opted to meet the predetermined objectives of achieving coordinated mink control. Thus, recruitment of volunteers to operate rafts was targeted toward individuals with an interest in nature conservation and natural resource management, such as forest or local government rangers, fishing ghillies, bailiffs, nature reserve managers, but also included numerous local residents made aware of opportunities to become involved in the project through community talks and publication in the local press. Where required, project officers would check mink traps or despatch mink themselves but volunteers were always encouraged to step up their involvement from monitoring rafts only, to trapping or becoming a trained despatcher.

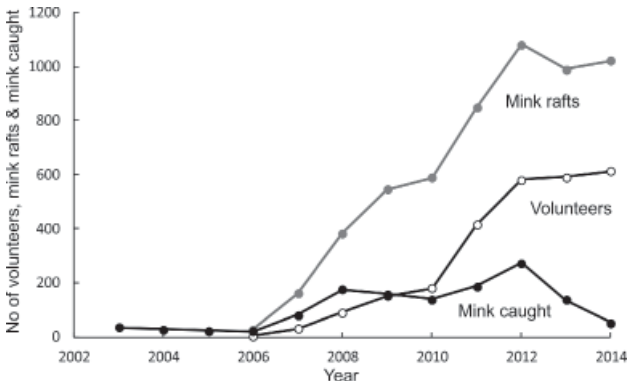

Fig. 3 Temporal dynamics of the number of mink caught per year (black line, black circles), the number of mink rafts deployed (grey line, grey circles) and the number of volunteers contributing to the projects (black line, white circles).

The large project area was subdivided into sub-catchment management units encompassing major tributaries of main catchments (median size: 55 km^2). Analyses of the impact of culling on the population used, as a reference point, the time when mink raft deployment was deemed complete in a sub-catchment by the local project officer. The number of mink captured per km of waterway decreased from an average of 0.16 to 0.06 to 0.01 for sub-catchments in the first, second and third years after inception of control, respectively. This was despite higher fecundity amongst mink that had survived culling (Melero, et al., 2015; Oliver, et al., 2016). Most mink caught in the third year after inception of control were males, reflecting their high propensity to disperse from the natal area. This was also reflected in the high proportion of juvenile males amongst the few mink caught in the higher elevations of the CNP which were cleared of mink by the end of 2007. No mink at all were caught in 3,417 km^2 of montane and moorlands areas of CNP but 376 mink were removed from 5,381 km^2 covering moorland and pastoral areas of lower altitude. There was further evidence of high mink mobility within and between river catchments resulting in compensatory immigration, as mink capture rate in a sub-catchment increased with connectivity to mink still present in other sub-catchments (Bryce, et al., 2011; Oliver, et al., 2016).

The key lessons from the ongoing evaluation of management efforts were:

i) The presence of large-scale lowland-highland source-sink dynamics in mink such that most mink impacting upland biodiversity had dispersed from more productive lowland areas. This motivated a change in the scope of the project when the management group endorsed downstream expansion from 5,500 to 10,570 km^2 at the end of the second year of the project (2007) so as to deplete mink where most were born (Fig. 1).

ii) Deploying a large number of mink rafts and recruiting volunteers is a gradual process and a pool of volunteers must be replenished to make up for volunteer turn-over (Beirne & Lambin, 2013). Different communities and river trusts vary in their ability to embrace conservation volunteering and the resulting asynchrony in the inception of mink control delayed region-wide eradication.

iii) Mink disperse widely and dispersal connects major river catchments, implying an inter-dependence between river catchments and the organisations that manage them. Thus, high mobility of mink dictates that control should be on a very large scale so as to avoid the effects of compensatory immigration.

The Scottish Mink Initiative (2011–2015): 10,570 –29,000 km2

The achievement of the Cairngorms Water Vole Conservation Project elicited much enthusiasm from volunteers who had been part of a rare conservation good news story, as well as from private and public land managers (e.g. CNPA) and Scottish Natural Heritage. As the three-year funding period was coming to an end, there was a real risk that the project would fall from a funding cliff edge such that not only would all biological gains be lost but the volunteer community would become despondent if abandoned. SNH had also been working with the Scottish Wildlife Trust (SWT) and local fisheries' trusts in the north-west Highlands to remove mink in that area, so there was an opportunity to develop a more strategic approach to mink control across the north of Scotland by amalgamating and expanding the various projects into a single, much larger

scheme. SNH, along with two other key funders (CNPA and the Tubney Trust) expressed their willingness to renew their funding commitments for a further three years (£478,000; £8,932; £100,000, respectively). However, the partnership research grant scheme run by the UK research council had been discontinued and funding commitments did not include the overheads universities expect from research grants. This made it impossible for UoA to continue as the lead partner of what was increasingly an ambitious conservation delivery project rather than a combination of this and research. Furthermore, it was evident that local organisations managing common natural resources and representing private entities gaining economic benefits from harvesting salmon would be more appropriate long-term custodians of a mainland island project than a university and thereby ensure it had a long-term legacy.

Accordingly, a new partnership was formed involving Rivers and Fisheries Trusts of Scotland (RAFTS) and SWT. RAFTS was a charity with a formal objective comprising "the conservation and enhancement of native freshwater fish and their environments in Scotland". Twenty-six river trusts and foundations were members of RAFTS and it was already actively involved in (mostly riparian plant) invasive management. It had a strong track record in fundraising and project management for its members. It proved to be the ideal body to lead an expanded project and to ensure coordinated action using best practice by its member river trusts at a scale commensurate with the biological challenge posed by mink. Nine river trusts in northern and north-east Scotland were enlisted in a new partnership and they committed in kind resources to removing mink from their river catchments. The renewed funding commitments were critical in allowing an application to the EU-funded LEADER scheme operated by the Scottish Government. The aim of LEADER is to increase support to local rural community and business networks to build knowledge and skills, and encourage innovation and cooperation, in order to tackle local development objectives. A competitive application involving multiple local areas was assembled and further funds (£229,000 from LEADER, and £14,000 from river trusts) were secured, facilitating the appointment of three project officers and a coordinator employed by RAFTS. For the second time, mink control efforts in northern Scotland bounced back from a financial cliff edge.

Owing to the time required for the evaluation of the funding bid and recruiting new project staff, mink volunteers had been left without support or certainty on the future of mink control efforts during the 19-month gap that elapsed between the end of the Cairngorms project in October 2009 and the start of the new Scottish Mink Initiative (SMI) in April 2011. Over that period, a skeleton staff was retained from previous projects to maintain the volunteer and associated mink raft network prior to further expansion (Raynor, et al., 2016). This included one part-time member of staff from the north-west Highlands project. It had adopted a "*cordon sanitaire*" approach, comprising a double line of mink rafts intended to prevent mink from invading northern Scotland, following from recommendations in an unpublished report to SNH (Harrington, et al., 2008). That approach turned out to be flawed owing to mink dispersal abilities, evident in data collected as part of the Cairngorms project but that were unpublished at that time (Oliver, et al., 2016), and to the importance of the coastal environment in driving invasion range expansion (Fraser, et al., 2015).

Four newly appointed SMI staff had to be trained and build new trust relationships with volunteers previously supported by other staff. While some volunteers had continued with their activities in the intervening time and caught a minimum of 139 mink in 2010, many no doubt concluded that the project had come to an abrupt end and ceased their activities. This led to reinvasion of some of the project areas, especially in the vicinity of the crucial catchment of the River Don where inadequate local support had prevented progress with mink control as part of the Cairngorms project (contrast figure 2 in Oliver, et al., (2016) and figure 3 in Melero, et al., (2015)).

Once the full complement of project officers was again embedded in the local community and supported by local river trusts, the approach refined in the previous project was scaled up substantially by SMI resulting in 837 volunteers operating up to 1022 rafts and removing a minimum of 646 mink between 2011 and 2014. This resulted in a vast area encompassing ~29,000 km^2 bounded by seas becoming free of breeding mink as determined by the absence of footprints on mink detection rafts, the metric chosen by the steering group to gauge the effectiveness of the project (Fig. 1), hence increasing our ability to deal with the constant flux of mink moving up from the south. Mink were regularly detected in the southern and western edges of the project area (51 in 2014) especially, reflecting primarily immigration by males during the rut period. A more detailed account of its achievements and of some of the challenges encountered is found in Raynor, et al. (2016).

The Transition to Scotland's Invasive species Initiative (2018-2022): 29,500 km^2

One ultimate objective of SMI was to engender a sense of ownership of the mink management and wider biosecurity, considering the threat posed by aquatic invasives such as the salmon fluke (*Gyrodactylus salaris*) and the giant hogweed (*Heracleum mantegazzianum*), amongst the local fisheries trusts as appropriate to any mainland island project. There was also an aspiration to further build on the partnership by involving more and more trusts, as resources allowed. Thus, during the second half of the funded period (September 2013–August 2015), there was a process of hand-over of all local processes to 10 local rivers and fisheries trusts. This included transfer of responsibility for managing existing networks of volunteers and mink rafts, including all access agreements with land owners, health and safety and standard operating protocols, and all relevant databases. A project coordinator remained employed by RAFTS and each participating river trust received payment to cover costs incurred in undertaking a combination of mink raft checking and maintenance, as well as data collection and support and coordination for the local volunteer network.

Two main limitations to the effectiveness of the handover have been: 1) not all areas of high mink productivity on the lowland coastal plain in the extreme corner of NE Scotland have sufficient salmon resources to maintain functional river trusts. Without additional resources, such areas could again become a source of dispersing mink into adjacent better controlled areas; 2) maintaining mink raft coverage in remote areas of north-west Scotland, where the low human population density; a predominance of red deer over grouse as the primary game species; difficult topography including many coastal islands; and a limited road network all placed significant restrictions on the ability to maintain required coverage for surveillance. The handover arrangements have been severely tested, with mixed results, by the absence of any financial support to any of the trusts between August 2015 and November 2017. During this period, a major reform of freshwater fisheries governance that would have led to river trusts and boards being disbanded was mooted by the Scottish Government and this precluded the submission of grant applications for the successor project by RAFTS.

The proposed reform was ultimately abandoned but led to the demise of RAFTS as an organisation. Scottish Natural Heritage, a key long-term supporter of the project from its very outset, stepped in as lead partner for an application to the Heritage Lottery Fund and an award of £1.59M was announced in August 2017. Thus, after a protracted period without secure funding, a successor to SMI, centred on applying the citizen conservationist approach to a suite of riparian invasives and prepared by RAFTS, will operate from 2018–2022. The new project, the Scottish Invasive Species Initiative, will tackle the challenge of reviving the volunteer network and undoing unavoidable partial reinvasion of the project area for another four years and further increase engagement in invasive management by local communities (Horrill, et al., 2019).

DISCUSSION

Over 15 years, a vast mainland island area has been established in northern Scotland that protects native riparian biodiversity including water voles from the destructive influence of the invasive American mink. The endeavour is the outcome of a succession of research and implementation projects conducted in partnership that optimised mink control effort so they could be scaled-up. Implementation projects progressed from a small-scale pilot phase (in the Ythan), to a two-stage demonstration phase, first evidencing the feasibility of scaling up mink raft deployment and enthusing volunteers to become citizen conservationists (the Cairngorms project) and then, the feasibility of devolving management of such a large scale project to local organisations engaged in natural resource management (the SMI) according to a wider, more strategic framework. The later stage of SMI was the beginning of embedding mink control within the activities of rivers trusts working autonomously but in a coordinated manner. The most recently funded successor project has the ambition to extend the approach refined with mink to a suite of containable riparian plant invasives that are widespread in Scotland.

Long-term invasive species management was achieved despite short-term funding as a result of a succession of fixed-length short-term discrete projects each of three to four years duration, rather than the result of any integrated long-term joined-up endeavour underpinned by secured funding or any strategic decision on the size of any area where mink could be controlled on Scotland's mainland. As the feasibility of controlling mink on a large scale was demonstrated and the endeavour's spatial ambition grew, the very existence of the project was in jeopardy on multiple occasions and some of its achievements were eroded during four gaps between funding cycles. Its future is secured for another four years after the latest two and a half year funding gap since the end of SMI. Although the large spatial reach of the project, its cost effectiveness and hence attractiveness, results from the use of volunteer citizen conservationists, the lack of continuity in funding has been highly detrimental to the trust relationship built between the project and volunteers giving their time freely for conservation. Invasive species control in mainland areas is, by definition, an open-ended commitment and it is paramount the limited resourcing required to maintain what has been achieved should be in place conditionally on evidence of success and sustainability being presented.

The cumulative cost of all components of the project, including the research by EU-funded fellows and four PhDs that enabled the project or contributed to its evaluation under the adaptive management, was £2,800,000. The cost-effectiveness of the project resulted from the use of a workforce of 866 unpaid "citizen-conservationist" volunteers. Based on the assumption that their time contribution amounted to 30 min/2weeks = 13 hours per year per volunteer, the total 2,652 volunteer years is equivalent to 21.6 standard person years, crudely valued at £1,404,00 using the assumptions of Robertson, et al. (2019). Arguably, the value of their contribution is greater still because of the increased awareness of the issues caused by invasives and community cohesion benefits (Evely, et al., 2011).

Although the volunteer approach is relatively cheap, it is not cost-free as volunteers require a degree of support, encouragement, information and re-supplying by project staff. The successive incarnations of the mainland mink control efforts have involved an increasing number of volunteers (peaking at 612 in 2014 Fig. 3) supported by a fixed and small number of project officers. Volunteer retention over time is less than 100 % such that it is constantly necessary to recruit new volunteers. Despite project staff consistently reinforcing the message that "no mink is good news", it remains that the enduring absence of mink on a volunteer's raft contributes to some volunteers dropping out (Beirne & Lambin, 2013). The greatest risk causing volunteer drop-out is the perception that the project has come to an untimely end in the absence of communication from project staff, as arose during the funding gaps, even if efforts to fund-raise for a successor project are underway.

SNH, Scotland's governmental organisation responsible for the management of natural heritage including the threat posed by invasive species, has been an enduring and crucial funder at all stages of mainland mink endeavour ever since 1995. It contributed 45 % of the total £2,803,950 cash cost over 21 years and 62% of the subset (£1,900,000) spent on conservation delivery. SNH is also the main funder of the Hebridean Mink Project (Macleod, et al., 2019), hence is committing substantial resources to managing American mink. However, as with all government agencies, including in New Zealand and the USA, it is constrained by its inability to commit long-term funding for managing established invasive species. Even SNH's Species Action Framework scheme that made sizeable financial contributions to SMI (£710,000 including extensions) was a five-year programme of targeted species management. Furthermore, contributions from SNH were conditional on funding being secured from other funders. Fund-raising by UoA and RAFTS was successful but time-consuming and added complexity to project management and reporting. It is a major concern that given EU funds covered 20 % of total costs and provided for 40% of the research work, the departure of the UK from the EU in 2019 will potentially leave a major hole in funding.

Through all phases of the project, the programmes of research that enabled and evaluated the development of large scale invasive control were always funded by separate funding streams to those used for conservation delivery (such as species recovery or habitat management). This was in response to implicit or explicit indications that while funders of conservation delivery like the sound of adaptive management, they are less keen to pay for it. The modicum of adaptive management achieved resulted largely from universities having access to lots of (predominantly) young, enthusiastic people keen to gain qualifications in conservation through applied research. For adaptive management to be a reality and not just an aspiration, there is a clear need for more integrated (research–management) funding streams delivering vital continuity of support.

Our work demonstrates there is no technical difficulty in expanding working with citizen conservationists for pushing back huge scale invasion. Partnerships and relationships had a critical role in achieving this work (across all project phases). The outcomes have been

achieved through those networks and the empowerment of volunteers and interested/affected 'stakeholders', all in spite of repeated uncertainty of funding. There is little doubt that even more could have been achieved had continuous funding been in place. Indeed, short-term funding is a major impediment to efficiency and increases the overall cost of long-term invasive control as lost ground must be recovered. Repeated gaps in funding, associated staff turnover and re-badging of projects are all damaging to the trust relationships built with volunteers. It makes no economic sense to embrace long-term control of invasives without funding it. Scotland, like other countries, needs a long-term stream of funding if it is going to manage invasive species. Thus, the future will tell whether our efforts were bold and trail blazing or overly ambitious and ultimately wasted if the SMI's ambition to become embedded within local management practice in perpetuity is not borne out.

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