Lessons on effectiveness and long-term prevention from broad-scale control of invasive alien species in Scotland's rivers and lochs

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Abstract Prior to 2008 there were few invasive alien species (IAS) initiatives operating in Scotland on a scale required for effective control. The establishment of the Biosecurity and Invasive Non-Native Species Programme by the Rivers and Fisheries Trusts of Scotland was the first attempt to link local efforts with national IAS strategy on scales appropriate to the effective control of target species. The programme worked with 26 local fisheries trusts to produce biosecurity plans that covered over 90% of Scotland's rivers and lochs. The programme implemented a range of prevention measures, including promoting awareness of invasive species issues and the need for biosecurity among water users. Projects were established for invasive plants on most major river systems, and for American mink (*Neovison vison*) in the north of Scotland. These projects involved public/private partnerships, using a mix of professional staff and volunteers. Interactive data management systems were developed to manage input from a large number of individuals and to inform an adaptive-management approach. These control projects demonstrated that it is feasible to reduce the size and density of target populations of invasive species across large geographic areas. The key to maintaining the momentum of this control effort in the future will be to demonstrate sustainable IAS management in the longer term. This challenge led to the formulation of the Scottish Invasive Species Initiative (SISI) whose overall aim is the development of a long-term, cost-effective strategy for IAS management throughout the north of Scotland. SISI will test strategies derived from experience and information from previous control projects. Important areas that the initiative will seek to address include defining outcomes, integrating IAS management into other management initiatives, and maintaining partnership interest and cohesiveness in a challenging funding environment.

Keywords: adaptive management, biosecurity, community-based effort, giant hogweed, Himalayan balsam, IAS, Japanese knotweed, mink, rivers

INTRODUCTION

Scotland depends on the quality of its iconic natural environment for economic and recreational wealth. The high number of protected sites (1,868) and designated natural features (5,376) reflects the importance placed on natural heritage.

Watercourses are integral, defining features of Scotland's landscapes and culture. Historically, Scottish society relied on healthy rivers and lochs for food, recreation, transport and industry. Art, folklore and traditional activities have long drawn inspiration from them. Today, the economic reliance extends to whisky-distilling, salmon-farming, tourism and many new forms of recreation. In 2010, Scottish residents generated £2.3 billion from their visits outdoors (SNH, 2011). Recreational freshwater fishing is estimated to support around 4,300 jobs, contributing £79.9 million to the economy (Marine Scotland, 2017).

Within increasingly fragmented landscapes, water courses also function as corridors between habitats for biodiversity. This vital function is compromised by invasive alien species (IAS) (Also known as Invasive Non-Native Species (INNS) in the United Kingdom) for which rivers and lochs are excellent pathways into the broader natural environment. The margins and shorelines of watercourses themselves are among the most exposed to the risk of IAS spread and damage. Climate change, pollution and habitat disturbance accelerate rates of invasion, with corresponding costs for socio-economic, human and ecological well being (Forest Research, 2008; Williams, et al., 2010).

The UK and Scottish Governments have recognised the IAS threat. The Great Britain Invasive Non-Native Species Strategy (GBNNSS, 2008) is a policy and strategic response. The Scottish Environment Protection Agency (SEPA) addresses the threat through the INNS supplementary plan to the Scotland and Solway-Tweed River Basin management plans (SEPA, 2009a; SEPA, 2009b). Scottish Natural Heritage (SNH), a Scottish Government agency, has included IAS in its Species Action Framework (Raynor, et al., 2016).

Prior to high level recognition of this sort, the vast majority of reponses to IAS were small-scale and localised. Management on larger scales was confined to catchment-based control of invasive alien plant species (IAPS) on the River Tweed (Tweed Forum, 2006) and to control of American mink (*Neovison vison*) in the Cairngorms National Park and rural Aberdeenshire (Bryce, et al., 2011).

The scale of the threat, the likely severity of ecological, social and economic impacts and the prospect of rises in control and eradication costs have constituted a case for better, more strategic and systematic approaches to managing IAS. This paper reports on the results and lessons learnt between 2008–2017 from the work of 26 member organisations of the Rivers and Fisheries Trusts of Scotland (RAFTS) in partnership with government agencies and universities to address the IAS threat to Scotland's rivers and lochs. We will also refer to an ambitious project in which those lessons are incorporated to manage multiple IAS cost effectively in the long term over 29,500 km^2 of northern Scotland.

METHODS

Biosecurity planning

At the northern invasion front for high-impact IAS of the United Kingdom and Europe, Scotland was well placed to manage the threats strategically at national and local scales. On the national scale there was an opportunity to defend the IAS-free region to the north of the front, control IAS in the lightly infested catchments in northern and southern Scotland, before addressing the more impacted areas of central Scotland.

RAFTS and its 26 local Trust members created area-specific biosecurity plans in three phases between 2008 and 2010 (Fig. 1). All plans used a template designed by RAFTS in consultation with the Great Britain Non-Native Species Secretariat, Scottish Government, SNH and

In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) (2019). Island invasives: scaling up to meet the challenge, pp. 458–465. Occasional Paper SSC no. 62. Gland, Switzerland: IUCN.

SEPA. The template linked key elements of IAS policy and strategy to local action and acted as a framework for universal consistency. Plan objectives reflected the three key elements of the Great Britain INNS Strategy (GBNNSS, 2008): (1) prevention, early detection, and surveillance; (2) monitoring and rapid response; and (3) mitigation, control and eradication. Objectives and actions were also linked to related plans and initiatives such as River Basin Management Planning (SEPA, 2009a; SEPA, 2009b). This approach translated the key elements of national policy and strategy into action across relevant sectors in ways which emphasised coordination and partnership.

Funding secured for a series of projects from 2009 to 2017 enabled local organisations to coordinate and monitor the control of invasive alien plant species and American mink by professionals and volunteers (Table 1). RAFTS provided the overall coordination, strategic direction and evaluation of the activities. SNH, SEPA, the University of Aberdeen (mink) and Queens University Belfast (plants) provided specific technical support. Principal target species were the IAPS, giant hogweed (*Heracleum mantegazzianum*), Japanese knotweed (*Fallopia japonica*) and Himalayan balsam (*Impatiens glandulifera*) and the alien invasive mustelid American mink – all recognised as high-impact species for waterbodies and/or biodiversity (UKTAG, 2015).

Engagement

Engagement of key stakeholders was critical given the scale of the work, the need to obtain permissions for access and the recruitment and maintenance of the volunteer workforce. Awareness campaigns, mailshots, presentations, meetings with local environment/community groups, schools and individuals, newsletters, the websites and media were means to initiate contact with potential volunteers. Working in public areas and approaching landowners for permission also proved effective in engaging local communities.

Once engaged, stakeholders were kept informed through websites, newsletters, media and meetings and later through interactive reporting systems. Participating organisations and individuals received skills-training for efficient, effective, legally compliant surveillance and control of IAS. Formal training courses were tailored to roles in the control strategy. Volunteers were also offered informal training if they were unavailable for formal courses.

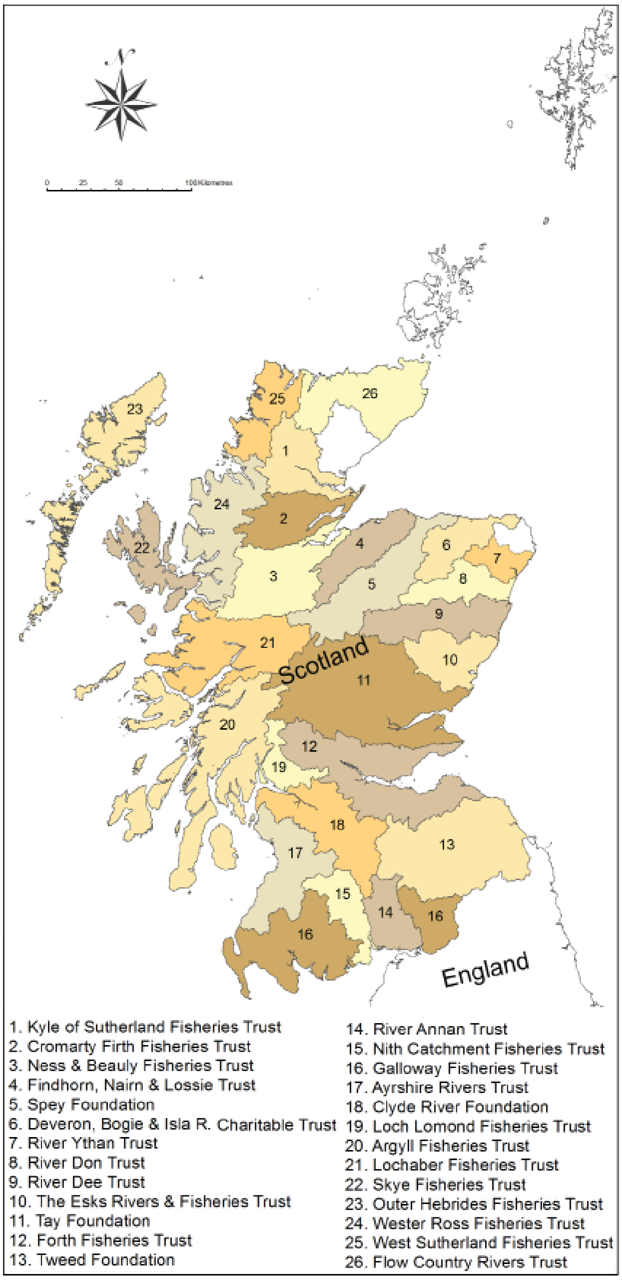

Fig. 1 Map of Trust areas.

Table 1 Summary of projects implemented through the RAFTS Biosecurity and Invasive Non-Native (Alien) Species Programme with duration, description of activities and geographic scope and participating local partner organisations.

Name of Project	Duration	Description	Participating Trusts
Pan Scotland Invasive Non Native Plant Species Control	2009–2016	A series of projects for the control and eradication of invasive alien riparian plant species in northern, southern and central Scotland. Included biosecurity, awareness and training of professional staff and volunteers.	Annan; Argyll, Ayrshire, Cromarty Firth; Deveron, Isla and Bogie; Don; Dee; Esk River; Forth; Findhorn, Nairn and Lossie; Galloway; Lochaber; Kyle of Sutherland; Tweed; West Sutherland
Scottish Mink Initiative (SMI)	2010–2015	Aiming to eradicate breeding mink from 20,000 km^2 (later extended to 28,000 km^2) of north and north-eastern Scotland. The Initiative also supports awareness and local capacity building activities as well as the development of local management models for future mink control.	Cromarty Firth; Deveron, Isla and Bogie; Dee; Don; Esk; Findhorn, Nairn and Lossie; Spey, Tay, Ythan
Controlling priority invasive non-native riparian plants and restoring native biodiversity (CIRB)	2010–2014	Control and eradication of invasive alien riparian plant species in 12 catchments in southern Scotland, piloting biosecurity, awareness activities, training of Trust staff and volunteers, best practice identification and dissemination.	Argyll; Ayrshire; Galloway; Tweed Forum

IAPS densities, distribution and control

Surveys of river and loch catchments identified the location, extent and abundance of IAPS. The distribution of IAPS populations were entered into a geo-database along with estimates of abundance based on the DAFOR scale (Kent & Coker, 1992). The impact of treatment was monitored by recording distribution and abundance post-treatment. Treatments varied by species but were primarily foliar leaf spray (Japanese knotweed and Himalayan balsam), stem injection (Japanese knotweed) and physical removal (Himalayan balsam).

Initially the majority of local Trusts took a 'top down' approach to control, starting at the upstream extent of IAPS distribution and working downstream. The rationale was the reduction of potential reinfestation of treated sites from upstream populations. Later, working from the lower to the upper catchment was adopted by some Trusts when treating whole catchments. This tactic recognised that plants lower in the catchment developed earlier than those in the upper regions.

Mink control

Volunteers and paid staff relied mainly on mink rafts to detect and trap American mink. Originally conceived by the Game and Wildlife Conservation Trust (GWCT) (Reynolds, et al., 2004), the mink raft is a floating platform on which a tunnel covers a clay pad. The raft is anchored to the bank of a waterway. American mink are predominantly active within 10 m of waterways (Yamaguchi, et al., 2003), are naturally attracted to tunnels and leave footprints in the clay when investigating them. Once a mink is detected, a live-capture cage-trap is inserted in the tunnel. Captured mink were despatched humanely. Carcasses were tagged and sent to Aberdeen University to determine sex, age and provenance based on genetic profile (Fraser, et al., 2013; Melero, et al., 2015; Ruiz-Suarez, et al., 2016).

Evaluation

Stakeholder engagement and impacts on IAS populations were evaluated in 2015 as measures of success. Data recorded for stakeholder engagement included contacts, background, and time spent. Assessment of mink control recorded raft locations and status, raft checks, mink sightings and captures. The locations and extent of target IAPS were recorded using geographic positioning systems and abundance by percentage cover or the DAFOR scale.

From 2012 data recording by volunteers and professional staff used specifically designed digital tools that not only managed data but also fed back information to users. The web- and map-based interactive geo-database for IAPS management made it easy to acquire survey and monitoring data and to translate changes in IAPS treatment status and abundance to maps presented on the website. An online platform, the MinkApp was developed in collaboration with Aberdeen University's dot.rural initiative (http://www.dotrural.ac.uk/) for the recording, management and presentation of data derived from American mink control. The MinkApp used natural-language-generation (NLG) to inform volunteers by email of mink captures and sightings in their area.

Trends in mink detections and captures were used to determine whether large-scale coordinated control efforts had had an impact on mink populations. The best (least biased) impact data were derived from the checking records for mink rafts. Detection rates could be calculated from the percentage of raft checks where mink footprints were observed. Further analysis through a generalised linear mixed effects model (GLMM) was carried out on long-term mink detection data from three test catchments: the Dee, Spey and Ythan where control had been ongoing since 2006 / 2007 (Bryce, et al,. 2011; Lambin, et al., 2019). The GLMM model accounted for differences among catchments, which was fitted as a fixed effect and as an interaction with time of mink control (i.e. the effect of mink control was allowed to vary by catchment). Non-independence between multiple records from the same raft(s) was accounted for by fitting raft as a random effect.

The effectiveness of IAPS treatment was assessed by the area cleared of infestation (i.e. no regrowth occurred for a year or more), the percentage decrease in coverage and the number of sites in a low maintenance state (DAFOR ≤ 1 (Rare) = 1–10% coverage) before and after treatment. Where coverage was recorded using the DAFOR scale, the mid value for each category of the index was used. Use of DAFOR categories, although simpler to record, encompasses score ranges of 10–25% and therefore more subtle changes in IAPS coverage may not be apparent with this index.

RESULTS

Stakeholder engagement

Throughout the reporting period a total of 1,000 volunteers serviced 2,020 surveillance points for mink control (Fig. 2) and at least 391 volunteers participated in IAPS control, contributing ≥ 2,587 hours of work. Actual numbers at any given time varied, being dependent on the size of area being managed and funding availability. In 2015 there were approximately 800 volunteers participating in mink and IAPS control. Continual recruitment was necessary to offset loss of volunteers. Volunteers left because of a number of reasons. A small but significant number decided it was not really something they wanted to do shortly after recruitment. Other reasons were moving from the area, changed employment and boredom.

Volunteers participating in mink control were from a broad range of backgrounds. Residents of the area with no

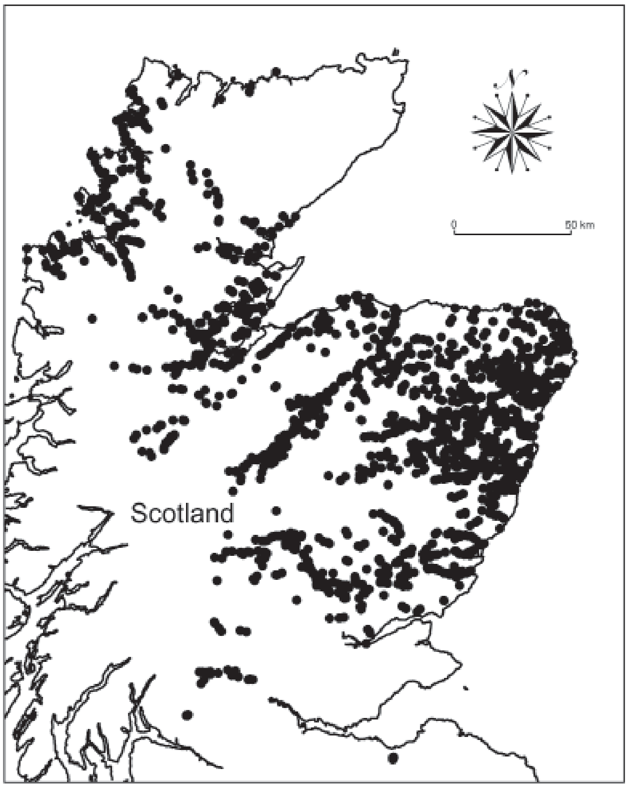

Fig. 2 Location of the 2,020 surveillance points (rafts, tunnels, traps) monitored for American mink between 2006 and 2015.

connection to the local environment constituted the largest proportion, followed by two professional groups – estate workers (game keepers and land managers) and fisheries personnel (managers, owners, guides and anglers). These three groups provided 78% of volunteers. The remaining 22% came from conservation organisations, government agencies and local councils, the tourism and leisure industry, farmers, fish farmers and University staff.

The degree to which individual volunteers engaged with control activities varied greatly, with most content with participating in surveillance e.g. checking mink rafts. However, a relatively small but significant proportion of volunteers, in terms of their contribution, received instruction for skilled activities e.g. humane despatch, stem injection and foliar spray near watercourses. These latter tasks required informal training and/or certification and increased commitment from the volunteer and host organisation.

There was only one landowner where there was issue with gaining access to land despite the large geographic area and the number of landowners involved. Access permissions were initially given verbally but insurance requirements meant that written permissions were increasingly required.

American mink

Across the entire control area, and considering all raft-check records in a calendar year, there was a steady decline, from a positive check rate of around 0.14 in 2011, to a low of around 0.02 in July 2015 (Fig. 3). The majority of the 86 positive raft checks towards the end of the study period (from a total of 2,776 recorded in the period July 2014 to July 2015) were concentrated along the frontier of the project area, which was consistent with frontier catchments receiving an influx of dispersing mink from outside of the control area and the coast.

Trends in mink captures followed those of the detection rate, with a decrease from over 280 in 2012, to only 98 mink captured in the 12 months prior to July 2015. Although mink were captured across the raft network, the areas with the highest numbers of captures reflected the optimum habitat for mink and the history of control effort. In agreement with the mink raft detection data, nearly all of the captures in 2015 were from lowland or coastal areas, indicating an overall contraction of the mink population both in range and population size (see also Lambin, et al., 2019).

The GLMM analysing how mink detection rate changes with year of mink control, showed a clear and statistically significant ($P < 0.0001$) negative relationship (Fig. 4; Table 2). Based on the fitted curves, the model predicts that

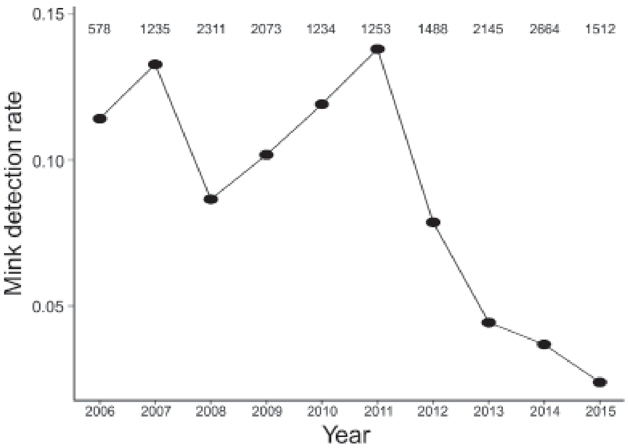

Fig. 3 Changes in the mink detection rate (number of positive raft checks / total number of raft checks) per year of coordinated mink control. Numbers above the points show the total number of checks from which the rates are estimated.

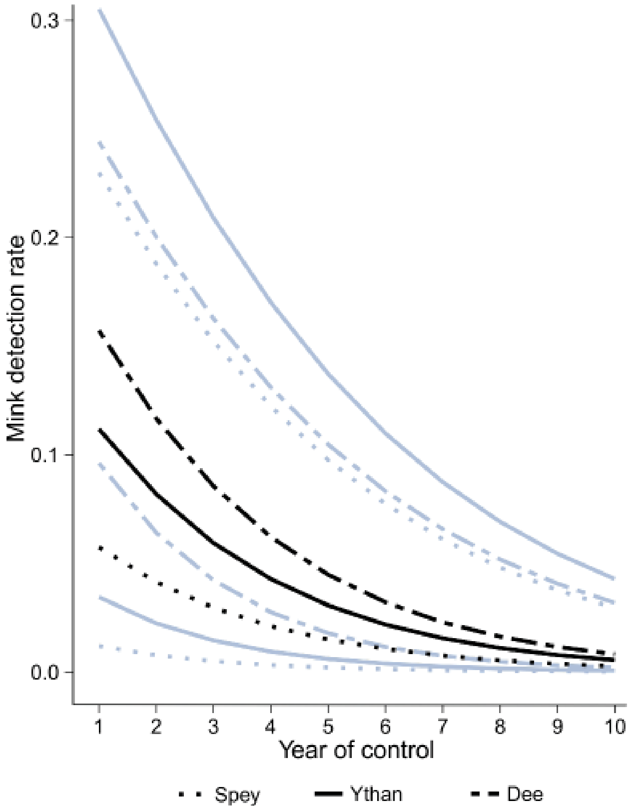

Fig. 4 The effect of control on mink detection rates (abundance) calculated by a generalised linear mixed effects model (GLMM). The black lines are fitted curves for the Dee, Spey and Ythan river catchments The grey lines areas are 95% profile confidence intervals.

Table 2 Summary table for a generalised linear mixed model (GLMM) analysing the relationship between mink detection rate (per raft check) and the year of mink control (by river catchment). Data are for the rivers Dee, Spey and Ythan. Observations is the number of raft checks. Groups refers to the number of rafts.

Observations: 9086	Groups: 399	Residual d.f. 9079	Variance: 1.57	St. dev: 1.25
	Estimate	S.E.	Z value	P value
Intercept	-1.33	0.24	-5.67	< 0.0001
Year of control	-0.35	0.05	-7.27	< 0.0001
Catchment (Spey)	-1.12	0.44	-2.58	0.01
Catchment (Ythan)	-0.55	0.30	-1.85	0.06
Year of control: Spey	0.00	0.10	0.02	0.99
Year of control: Ythan	0.15	0.06	2.54	0.01

mink abundance will be reduced to ca. 40% of the starting abundance in four years and further to around 6% of initial levels after nine years. A large amount of the uncertainty in the model's predictions (illustrated by the 95% confidence intervals [grey lines] in Fig. 5) is attributable to differences between the catchments, rather than the overall estimate of the effect of mink control (Table 2). This was particularly true of one catchment where the mink population remained high before dropping abruptly after control in the adjacent catchment.

A small number of rafts influenced trends significantly with a majority of rafts never detecting any mink footprints. All information on mink presence came from 36% of rafts (n = 357) checked at least once. In fact, only 6% of checked rafts (a mere 59) accounted for 637 (53%) of the 1,307 detections. Whilst factors such as duration of raft placement and checking frequency may influence this result, the take home message is that a small portion of the raft network does most of the work in detecting, and vis a vis removing, mink.

Invasive alien plants

The 10 river Trusts that supplied information surveyed a minimum of 2,403 km of waterways (Table 3). Their surveys revealed that IAPS were widespread (extending over ca. 1,603,821 m^2) and had become a serious threat to riparian biodiversity and activities along Scottish river corridors.

Japanese knotweed was the most frequently encountered IAPS. Trusts recorded it in all survey areas though the extent varied significantly among them (Table 3). Giant hogweed was least prevalent and abundant. Three Trusts reported it absent and a fourth discovered only one small stand. But in all other areas infestations averaged > 4,000 m^2. In Ayrshire giant hogweed had invaded 188,000 m^2 . Himalayan balsam infestations proved to be the most challenging. This IAPS had reached 699,233 m^2 of river corridor. Stands in two catchments extended over tens of kilometres.

Table 3 Summary of the area surveyed (in metres) and area recorded as infested by each IAPS for each of the 10 trusts (reported as m^2).

	Area surveyed	GH	HB	JK	Total
Annan	197,000	20	200,000	11,364	211,384
Argyll	195,000	-	-	9,198	9,198
Ayrshire	739,000	188,000	204,000	257,000	649,000
Cromarty	300,000	27,000	128,500	54,500	210,000
Dee	170,000	4,176	32,938	41,768	78,882
FNLT	103,500	72,000	62,700	88,500	223,200
Galloway	114,000	4,196	75	21,663	25,934
Lochaber	42,400	0	0	43,500	43,500
Nith	160,450	41,955	70,430	39,718	152,103
WSFT	30,000	0	590	30	620
Total	2,403,834	337,347	699,233	567,241	1,603,821

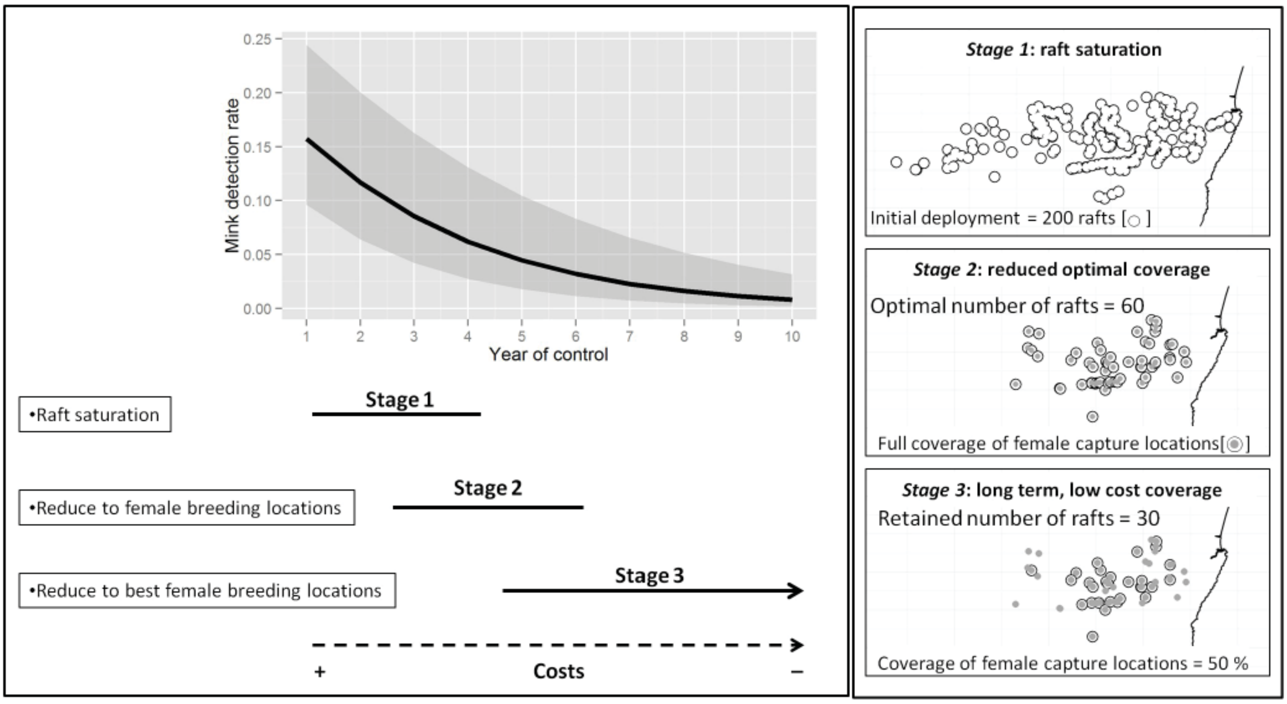

Fig. 5 Schematic of a graduated three-phase strategy for mink control (based on capture data from the River Dee, NE Scotland). In Stage 1 (years 1–4) mink abundance is at its initial maximum. The box on the right illustrates how the strategy moves from a saturated raft network in Stage 1, to cover all female capture locations in Stage 2, and only a subset of these in Stage 3.

Success in clearing areas of infestations was limited with 16%, 11% and 10% of the original area of infestation cleared for giant hogweed, Japanese knotweed and Himalayan balsam, respectively (Table 4). However, decreases in coverage between 50% and 80% were common for all three target IAPS.

The greatest decrease in coverage was for Japanese knotweed, with five areas achieving >85% decrease. Despite the reduced coverage, shoots from the sub-surface rhizome prevented sites from being categorised as cleared. Cover of giant hogweed fell by 53%–75%. However, there was mixed success in controlling Himalayan balsam (Table 4). Trusts reported that effective control of this IAPS was problematic as it is easy to miss individual plants hidden among native vegetation, or in areas of limited access. In four areas, Himlayan balsam was also anecdotally observed to quickly colonise sites that had recently been cleared of giant hogweed or Japanese knotweed. Of note, however, is that both Nith and Cromarty Trusts, using a targeted approach and a larger coordinated workforce, decreased coverage of Himlayan balsam by >82% (as well as clearing >29,000 m^2) across large areas.

Standardised percentage coverage decreased from a median of 38% (mean 33%) to 5% (mean 14%) in 447 pre-treatment sites following control. The majority of sites (327; 73%) showed improvement, 103 (23%) were recorded as having no change, and infestation levels at 17 (4%) had got worse. Around half the sites infested by giant hogweed and Japanese knotweed, and 38% of those by Himalyan balsam, were in a low maintenance state after treatment (Table 5). This was despite the reported increase of infestations of giant hogweed after the large floods of the winter of 2013/14.

Costs

The work reported in this paper was undertaken through the sequential securing of short-term (1–4 year duration) funding. Consequently funding was cyclical with periods of higher funding alternating with those of low or no funding (Fig. 6). Using northern Scotland as an example, the amount of funding secured for IAS work has increased in each subsequent funding phase, from £124,000 (1996–2005), £639,000 (2006–2009) to over £1.95 million provided in the period 2010–2015. The increased funding reflected the expanding geographic reach (from 5,000 km^2 to almost 30,000 km^2) and complexity of the work undertaken. This included the addition of IAPS control in 2009 and biosecurity, awareness, education and capacity building activities after 2010.

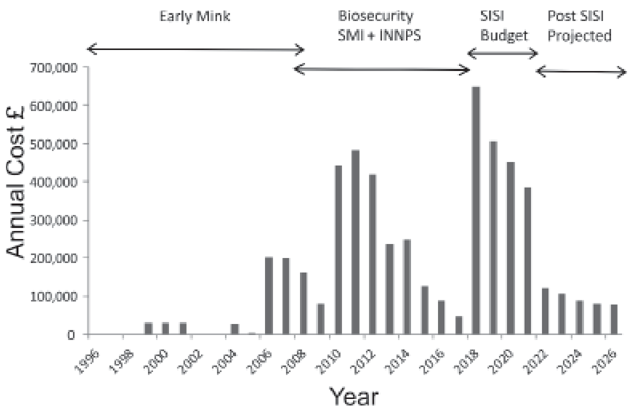

Fig. 6 Funding for IAS work in northern Scotland.

Table 4 Area cleared (no growth detected in post-treatment survey) in m2 and relative percentage decrease in mean coverage at infested sites for each of the INNPS and each Trust. A dash (-) indicates that no data were available.

	GH		HB		JK	
	Area cleared	**% decrease**	**Area cleared**	**% decrease**	**Area cleared**	**% decrease**
Annan	0	53	0	19	0	63
Argyll	-	-	-	-	8,070	88
Ayrshire	53,452	60	>6,684	25	29,722	47
Cromarty	750	57	38,000	82	7,750	81
Dee	0	0	0	0	0	65
FNL	-	75	-	-	-	-
Galloway	-	-	0	50	2,840	84
Lochaber	-	-	-	-	16,268	42
Nith	40*	-	29,871	94**	0	99
WSFT	-	-	0	90	30	100
Total	54,242		>74,555		64,680	

* The Nith group recorded the number of plants treated, rather than area cleared.
** Percentage calculated as change in the *number of plants* treated between initial (maximum) levels and final treatment in 2014.

Table 5 Number and percentage of the total number of sites that were in a low maintenance state before and after treatment for each target species.

		Before treatment		After treatment	
	Total no. of sites	**No. of sites**	**% of sites**	**No. of sites**	**% of sites**
Giant hogweed	468	82	17	243	63
Japanese knotweed	598	41	7	295	88
Himalayan balsam	293	40	14	111	100

DISCUSSION

Findings and lessons for future work

The control strategies and measures for both IAPS and American mink have had a demonstrable, although variable, impact in suppressing target populations in terms of coverage and population density over large geographic areas (see also Bryce, et al., 2011; Melero, et al., 2015; Oliver, et al., 2016). The variation in results suggests there is room for improvement in strategy and local implementation.

The use of an evidence-based approach, derived from evaluation of activities and research associated with the project, provided the central core of the adaptive-management strategy. The findings were utilised to improve control strategies (e.g. concentration of surveillance in lowland areas and along migration routes for American mink, control methods for IAPS, engagement and retention of volunteers, and implementation of management efforts at an appropriate geographic scale in defensible areas for all IAS). An example of the latter is that the GLMM analysis highlighted the importance of taking a coordinated multi-catchment approach to mink control as the number of mink in a catchment depends on control both within that catchment and in neighbouring catchments.

Working over such a large geographic scale, including urban areas, with limited secured funding was made possible by the use of a large trained volunteer workforce supported by professional staff. Staff were either employed by the project or from local organisations. The latter arrangement allowed the building of capacity for volunteer management and IAPS control within the organisations. Although this approach helped to build longer term management sustainability, it sometimes resulted in competing priorities between the project and the organisation. Employing dedicated project staff avoided this conflict but did not effectively address long-term sustainability, as employment ended with the cessation of project funding.

The use of large volunteer networks rather than increased numbers of staff reduced employment costs, a significant cost. However it did not reduce liability risk for the organisation(s) that supported the network. To mitigate risk as the project developed, RAFTS increasingly used written rather than verbal permission for volunteer participation and access agreements. The information and training given to volunteers increased, particularly regarding health and safety. Organisation policies and public liability insurance was also regularly reviewed in light of volunteer numbers and their work. Changes in project management structure required revision of all agreements. One outcome of these changes was that significant numbers of volunteers expressed concern and dissatisfaction with perceived increased bureaucracy, with a small number withdrawing their participation.

Management over such a large area required the building and maintenance of coordinated partnerships with defined roles for individual partners at both local and national level (Table 6). At the local level, non-government/non-profit organisations (Trusts) provided the hub of the partnerships and collaboration. The Trusts have close ties to sectors of the local communities, particularly landowners. At the national level RAFTS was the main contact point for government agencies and universities, and coordinated the work of the local organisations. Partnership arrangements were not pre-determined but rather developed over the course of the work and in response to the varied demands of the management strategies employed. Partnerships and collaboration involved over 70 organisations, including the Scottish Government, state agencies, local authorities, universities, >50 local non-government organisations and businesses and over 800 volunteers at any one time.

Coordination was generally effective but there were instances of inconsistency of approach and in data collection among local organisations (Arts, et al., 2013). Although consistency of data collection improved with the advent of the on-line reporting systems, ensuring consistency of approach and data collection among large numbers of local organisations remained a significant challenge.

Common interest formed the basis for collaboration. Differing characteristics of communities (individuals and community organisations) within and among geographic areas of Scotland meant approaches to engagement varied. The diverse composition of the volunteer base demonstrated that IAS control, particularly of American mink, provided a common base for a wide range of community groups, some of which had a history of conflicting interest (e.g. gamekeepers and bird conservationists). Motivational factors included professional or commercial interest and a concern for the local environment – as expressed by residents who made up a large proportion of the volunteers.

Taking action and demonstrating results were important factors in retaining participating volunteers and organisations. Demotivating factors included the breaks in project activities caused by short term funding cycles and perceived increased bureaucracy. The use of on-line reporting systems provided a means to disseminate progress and results through a limited functionality for data interrogation (mink) (Beirne & Lambin, 2013) and a map interface for IAPS. These reporting mechanisms became part of an overall volunteer and organisational recruitment and retention strategy that combined a variety of awareness activities with training and legal empowerment. Successful control also influenced volunteer retention with the lack of detection of IAS leading to boredom. Maintaining interest and motivation remains a critical long-term challenge for future management (Beirne & Lambin, 2013).

Despite repeated efforts to obtain long term funding, IAS control in Scotland has relied on short term, or project specific, funding. The resultant funding cycles occur as one project has to finish before funding for the next stage can be secured. Start-stop cycles result in a loss of staff, volunteers, equipment and, as a consequence, momentum, capacity and credibility (see also Lambin, et al., 2019). Furthermore, overall costs increase as start up costs (staff and volunteer recruitment, training, control) exceed recurrent costs of established projects.

Funders' regulations also influence the work that can be undertaken. The majority of short-term funders require

Table 6 Contributions by participating institutions.

Level of collaboration	Partnership organisations
Strategy	RAFTS, GB Non Native Species Secretariat, Scottish Environment Protection Agency, Scottish Natural Heritage, national park authorities (Cairngorms and Loch Lomond),
Management	RAFTS and 18 member Trusts
Implementation	18 local trusts, other non-government organisations e.g. (Scottish Wildlife Trust, Royal Society for the Protection of Birds), local authorities (Highland, Moray, Rural Aberdeenshire, Angus, North Tayside, Argyll and Bute, Ayrshire, Dumfries and Galloway.
Evaluation	RAFTS, University of Aberdeen, Queens University Belfast.

tangible benefits for their support. These benefits are more easily expressed in terms of IAS reductions than prevention (biosecurity), where no occurrence or a 'negative' result defines success. Regulations have also prevented funding being used for rapid-response, another key element of successful IAS management. Funding for IAS management should recognise that 'negative' results indicate success both in prevention and control, have flexibility to allow for rapid response and changes in approach required by adaptive-management and be available for work over appropriate geographic- and time-scales.

Although there is still no long-term funding of IAS control in Scotland, project funding has been secured for the Scottish Invasive Species Intiative (SISI) (2018–2022). SISI aims to develop a long-term, cost-effective management system for multiple IAS across 29,500 km^2 of northern Scotland. The project builds on the experiences of its predecessors and tests more focused strategies for IAS management.

One such approach to mink control derives from the variation in the relative contribution of individual rafts to overall detection rates, coupled with the analysis from the GLMM. The model predicts abundance will be more than halved following four years of control and reduced to < 10 % after ten years. Accordingly, capture data will be used to reduce raft coverage in three stages over the same timeframe (Fig. 5). If patterns of mink dispersal and settlement are influenced by habitat quality, despite the species's mobility and generalist habits, reductions would track capture rates for females. This assumes that populations under control pressure will reoccupy optimum habitat preferentially, and that concentrations of female mink will indicate where that is. Reactive redeployment may be required in response to localised increases in mink activity. If successful, the strategy will use the best available evidence and scientific understanding to substantially reduce costs.

Protecting non-invaded areas through awareness targeted to user groups (e.g anglers and boaters) and the use of biosecurity stations and individual biosecurity kits is a key component of the project. Habitat restoration using resilient native communities will be tested as a means to reduce reinvasion risk of areas cleared of IAS.

Emphasis is placed on strengthening the capacity of local organisations, so IAS management becomes part of normal working practices. SISI will also develop means to maintain volunteer participation over the timeframes required to manage IAS. Evidenced-based adaptive management is central to the strategic approach of SISI and the project will develop interactive and map-based data-recording systems.

SISI faces some significant challenges in balancing costs with outcomes, particularly in regard to reducing introductions and spread over such large geographic areas and defining what reduction in IAS can be sustained. Effective coordination, and quality assurance, of the work undertaken by multiple local organisations is not to be underestimated.

Despite the challenges, it is envisaged that by the end of SISI the more focused control will have suppressed target populations to levels where that suppression can be affordably maintained by motivated local organisations and their volunteer networks (Fig. 6, from 2022–2026). However, post-project IAS management in Scotland will still require additional funding to that provided by local organisations and at present it is not clear how that will be provided.

ACKNOWLEDGEMENTS

Funders of this work were: Scottish Natural Heritage; People's Trust for Endangered Species; Tubney Charitable Trust; Cairngorms National Park Authority; the Scottish Government and the European Community Cairngorms, Highland, Moray, Rural Aberdeenshire and Rural Tayside Local Action Groups LEADER 2007–2013 Programme: EU Interreg Iva: SEPA Water and Environment Fund, Local Trusts and various local funders. The authors would also like to thank Aberdeen University and Queens University Belfast for their technical support.

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