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Mink (*Mustela vison*) eradication to protect ground-nesting birds in the Western Isles, Scotland, United Kingdom

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Abstract Feral American mink are perceived as a growing threat to native biodiversity in Europe. We describe the planning and early stages of a campaign to eradicate American mink from part of a 2800 km^2 archipelago off the west coast of Scotland. The present programme will last 5 years and cost GB£1.65 million, funded by EU LIFE. It aims to protect ground-nesting birds, which are vulnerable to mink predation, and has been successful to date (>220 mink caught). Non-native feral ferrets are also being culled. This paper summarises early results of the campaign, and discusses its implications for full eradication on the archipelago and more widely in Europe.

Keywords American mink; *Mustela vison*; eradication; ground-nesting birds; ferret; Scotland

INTRODUCTION

Invasive alien species are the second most important cause of biodiversity loss on a global scale, and on island ecosystems they are probably the most significant cause (Clout & Veitch 2002). Many mammalian species that cause no conservation problems in their native communities have changed their behaviour when released onto islands, intentionally or accidentally. The result has been increasing numbers of local extinctions of indigenous species, and the global extinction of endemic species. Indeed, Coblentz (1998) suggests that predation by introduced alien species such as rats and cats has reduced global seabird numbers by tens of millions.

Many offshore islands around the United Kingdom have established populations of invasive mammals, originating from mainland Britain or from further afield. The American mink (*Mustela vison*), a small, semi-aquatic, generalist predator, established feral populations on mainland Britain in the 1950s and 1960s, following releases and escapes from fur farms. On the Isle of Lewis in the Western Isles (north-west Scotland), mink escaped from two fur farms established in the 1950s. The farms closed in 1962, but by then a wild population was already established. Mink were first noted in the wild in 1969 (Angus 1990), and the population they founded has since spread steadily southward, colonising nearly all of the island chain by 1999 (Fig. 1).

The islands were previously free of mammalian carnivores except the native otter *Lutra lutra*, plus feral populations of ferrets *M. furo* on some (North and South Uist and Benbecula). The southern part of the island chain is home to internationally important bird populations, so early attempts were made to stop mink crossing the Sound of Harris (Fig. 2), which is 8–10 km wide but dotted with many small islets. A limited trapping operation (1–2 trappers with approximately 100 traps) tried to remove mink from along the southernmost coast of Harris and adjacent offshore islands. These attempts failed, and breeding populations of mink were confirmed on the southern island group (North Uist and Benbecula) in 1999 (Harrington et al. 1999).

This paper outlines the early stages of a mink eradication campaign in the Western Isles. It is the largest eradication campaign in the United Kingdom since the successful coypu (*Myocastor coypus*) eradication of the 1980s (Gosling & Baker 1989). The primary aim of the work is to protect internationally important populations of ground-nesting birds. The paper summarises progress to date

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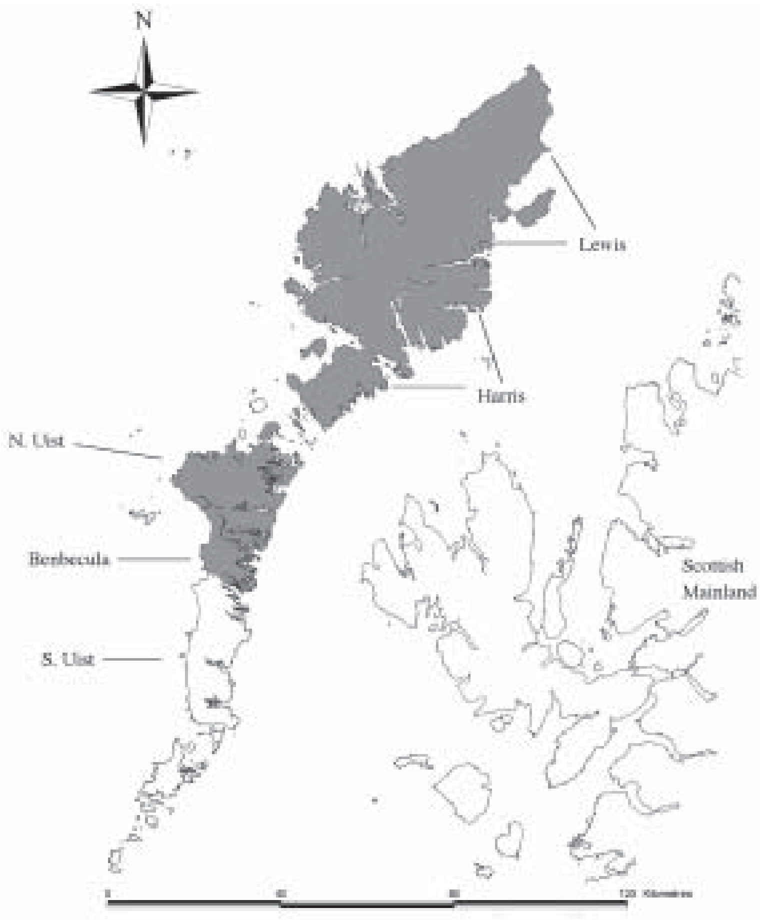


Fig. 1 Map of the Western Isles showing the areas that mink were known to have colonised (shaded) by 1999.

on the project, including preliminary trapping results for both mink and feral ferrets, problems that have been encountered, and some of the innovative techniques developed. The future direction of the project and its wider implications are also discussed.

STUDY AREAS

The Western Isles

The archipelago known as the Western Isles comprises a total land area of 2800 km^2 distributed among five main islands in a string, stretching 195 km from north to south. The nearest point on the Scottish mainland is 15 km to the east, a distance that is too large for mink to cross naturally. The habitats on the islands are varied, and include large areas of blanket bog and numerous lochs (lakes) and streams. Topographically, much of the archipelago is hilly, with a maximum altitude of 719 m. Access to parts of many islands is restricted, and for some is possible only by boat.

The climate is oceanic and cool temperate, with long periods of windy and wet weather (mean annual rainfall ranges from 1000 to 1800 mm). The most fertile areas are the base-rich meadows (a habitat known as *machair*) where shell-sand admixtures to the soil provide nutrients for small-scale agriculture. There are also extensive systems of unconsolidated dunes around sheltered coasts. The human population of the Isles is only about 20 000.

As on many island ecosystems, the natural mammalian fauna is restricted, and many of the species now present have been introduced. These include rats (*Rattus norvegicus* on most islands, plus *Rattus rattus* on two islets to the east of Harris), rabbits (*Oryctolagus cuniculus*), hedgehogs

Fig. 2 Map of the Hebridean Mink Project control area showing the PhD study area in South Harris (shaded).

(*Erinaceus europaeus*), and feral ferret. As a result of the historic paucity of mammalian predators, the islands have a rich avifauna, particularly of ground-nesting birds. The densities of some waders and farmland bird species on the southern islands of the chain are among the highest in Europe, and there are also internationally significant numbers of red and black-throated divers (*Gavia stellata* and *G. arctica*) and corncrake (*Crex crex*). There are also important populations of three species of tern: arctic (*Sterna paradisaea*), common (*Sterna hirundo*), and little (*Sterna albifrons*).

These colonial ground-nesters are particularly vulnerable to predation by mink, which generally take eggs or chicks but also occasionally adult birds. Mink, like many predators, are known to kill in excess of their immediate needs (Breault & Cheng 1988) and this behaviour can wipe out entire tern colonies in some years. These large-scale predation incidents may be caused by small numbers or even by individual mink. The long-term effects of these incidents are unclear however, because they often cannot be distinguished from the confounding effects of predation by other species (e.g., rats), and natural population fluctuations. Indeed, results from the Western Isles in the early 1990s showed that there was no significant short-term difference in breeding success of terns between mink-free and mink-colonised areas (Clode & Macdonald 2002). However, there were indications that terns were responding to mink presence by forming larger colonies in mink-inhabited areas. Despite these somewhat ambiguous results, however, it is clear that in some western parts of Scotland mink are causing widespread breeding failures at small tern colonies (Craik 1997). Similar events are being reported in other parts of Europe (Andersson 1999; Hersteinsson 1999).

Hebridean Mink Project (HMP)

After Harrington et al. (1999) confirmed that mink had reached the southern islands of the archipelago, it was clear that action was needed. First, a feasibility study was conducted (Moore et al. 2000), which concluded that more information was required (on population size, density in different habitats, trapping success, etc.) in order to estimate the chances of success and the probable costs of a full, island-wide eradication campaign.

Moore et al. (2000) recommended trying a preliminary, small-scale eradication on a defined management area, comprising 771 km^2 or 33% of the colonised area, to provide the data required. This, the Hebridean Mink Project (HMP) began in November 2001. It is a 4½ year campaign with a budget of GB£1.65 million (c. US$2.65 million), half of which is provided by the EU LIFE Nature Fund, a programme dedicated to protecting bird species and their habitats. The remainder of the funding has come from a consortium of six Government Agencies and NGOs. The project has two specific management aims: (1) eradicating mink from the islands of North Uist and Benbecula (area 533 km^2); and (2) dramatically lowering the population in South Harris (area 238 km^2) to reduce the risk of re-colonisation of the southern islands.

The project also aims to collect the data needed to model different potential strategies and estimate the resource requirements of a future eradication campaign for the whole of the Western Isles. The areas chosen for the HMP scheme represent most of the habitat types found in the Western Isles. We therefore expect to be able to collect data from a typical eradication campaign against mink populations at varying densities over different habitat types, providing realistic data for the associated models.

Further data are being collected through a PhD study funded by the project focusing on the response of mink (in terms of dispersal, habitat use, territoriality, and diet) to trapping in adjacent areas. The PhD study site is a 90 km^2 area (8% of the total HMP control area) in South Harris, which includes all the main habitats in the HMP control area (Fig. 2). These data should yield valuable information on mink population dynamics which will help to optimise the timing and spacing of future control operations. A significant modelling component has also been built in to the project to allow continuous monitoring of progress (HMP unpubl. data).

METHODS

The campaign employs a project co-coordinator, two foreman trappers (one on South Harris and one on Uist) and six full-time trappers. Additional seasonal and casual workers help as and when required, so the project has spatial and temporal flexibility in allocation of staffing resources.

The project also runs two Land Rovers, two all-terrain vehicles (ATVs) and two 5.7 m rigid-hulled inflatable boats (RIBs) allowing access to remote coasts and small offshore islands. Most of the transport needs of the trappers are met by use of their own cars.

The initial feasibility study examined the potential use of a range of control techniques including poisoning, fumigation, lethal trapping, and immuno-contraception (Moore et al. 2000). It concluded that live-trapping was the most publicly acceptable, humane, and successful technique, at least in the early stages of the campaign. Lethal-trapping may be used later on in the campaign, when numbers are low or for particular “trap-shy” individuals, but the risk of killing juvenile otters (and other non-target species) is considered too high for widespread use of kill-traps. Use of poisons was ruled out because there are none approved for mink in the United Kingdom. Poisons also entail unacceptable risks of non-target deaths and secondary poisoning, particularly of raptors (the Western Isles has important populations of golden (*Aquila chrysaetos*) and sea eagles (*Haliaeetus albicilla*)).

Fumigation of mink den sites is also not permitted, due to a lack of approved fumigants for mink and the possibility of killing non-target species such as otters. Overall, therefore, live-trapping is the most effective and publicly acceptable technique.

Mink are caught alive in $18 \times 15 \times 60$ cm cage traps. Although made of 3 mm gauge wire mesh, the traps have solid galvanised doors which can be seen and checked from a distance. Traps are checked daily when in use, and captured mink are killed with air pistols. Baits are mainly fish or fish oil, but sometimes also fresh or powdered eggs, or fish-farm pellets from salmon farms. Some traps have been set unbaited. Trapping commenced on 1 November 2001 and the results presented here comprise the data collected between then and 28 February 2003 (i.e., the first 30% of the planned duration of the HMP project).

Trap densities are reported as traps per km^2 and also (probably more appropriately for a semi-aquatic species) on the basis of traps per km of aquatic habitat. All trap locations are recorded on hand-held GPS units, which allow easy downloading of trap locations onto a GIS database, facilitates re-finding of traps, and allows trappers to move easily between trap lines. Most traps are placed close to water-courses: 43% in rocky shore habitat, 23% adjacent to inland lochs, and 20% adjacent to inland streams and rivers; 10% on moorland; 5% in dunes. At least some (non-catching) traps are regularly moved.

Potential population sizes for the whole of the Western Isles and the HMP area were estimated by firstly calculating densities in each of the three main habitat types occupied by mink in the PhD study population (rocky coastal, inland stream, inland loch). This was done by the capture-mark-recapture technique using cage traps over several months in the pre-breeding period. A total of 13 km of rocky coast, 5 km of inland loch and 6 km of inland stream were trapped, and 34 individual mink were caught in total. These data were then used to estimate the minimum number alive in each of the three trapped habitats, and a "linear density" (mink/km habitat) was derived. These estimated densities were then multiplied by the length of each habitat type both in the Western Isles and in the HMP area, to estimate pre-breeding carrying capacity.

A second population estimate was then made for the HMP area only. Instead of the carrying capacity this approach attempted to estimate the actual mink population at the commencement of trapping. First, the relationship between population size and the catch per trap night ($y = 0.003x + 0.12$, where y is the catch per trap night and x is the known population size) was derived from trapping of known populations in four areas of the well studied PhD study site. Then the HMP control area was divided into 16 sub-areas and the catch per trap night over the initial 7 nights trapping was calculated for each area. The relationship derived above was used to estimate the population size in each area from the initial catch per trap night in each area. The sub-population estimates were summed to estimate the total HMP mink population at the start of the trapping programme.

The effects of mink removal on the numbers and productivity of terns and gulls is also being monitored. This study will compare tern and gull numbers and breeding success in colonies within and outside areas colonised by mink, and will go on to compare the fate and success of these colonies as mink numbers decline.

From the outset we established a Project Advisory Group including representatives from all the contributing stakeholders to give the project overall direction and guidance. In addition to this, a Community Liaison Forum was set up to report on progress to interested groups in the local community. A proactive public communications campaign was launched before starting the fieldwork. This has included setting up a website as part of the Scottish Natural Heritage site (www.snh.gov.uk) and the production of quarterly Project Bulletins which are distributed to a wide range of interested local, national, and internationally based individuals and organisations. The HMP has also actively built up links with schools and other local interest groups, notably fish farmers, gamekeepers and naturalists.

RESULTS

The campaign had been running for 16 months at the time of writing (March 2003). Much of the first 6 months was spent training staff, procuring equipment, and establishing health and safety protocols.

Trapping effort

Trap densities range up to 5 per km in the most suitable habitat (rocky shores). Trap density is also locally far higher at individual den sites, as several traps are placed close to the den entrances until the mink is caught. To date, 2300 traps have been deployed semi-permanently in the field in 43 traplines of c. 50 traps. This gives a mean trap density (excluding the PhD study area) of 2.25 traps per km^2, although mean densities over most of the study area are $3.1/km^2$.

Within the first 6 months of the project, mink were discovered by fish farmers 30 km beyond their previously known range, in southern South Uist. This added an extra 343 km^2 (c. 45% of the previous total) to the area that must be trapped, increasing the total area to approximately 1114 km^2 (Fig. 2). To date, trapping effort in South Uist is still relatively low (0.6 traps km^2 compared with 3.1 traps km^2 for the rest of the HMP area) due to lack of resources.

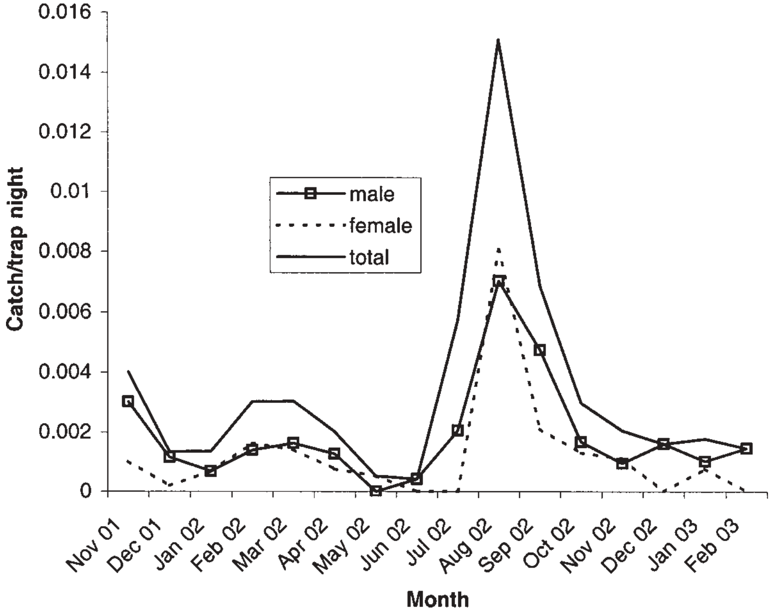


Fig. 3 Seasonal effects on trapping success (number of mink caught per trap night).

Table 1 Estimate of carrying capacity populations by habitat type, in the Western Isles and in the Hebridean Mink Project (HMP) area. The percentages of the total population are given in parentheses.

	Density, *n*/km in untrapped populations	Carrying capacity in the Western Isles	Carrying capacity in the HMP area
Rocky shore	1.01	3391 (71.6%)	1795 (79.2%)
Inland stream	0.209	435 (9.2%)	75 (3.3%)
Inland loch	0.178	912 (19.2%)	396 (17.4%)
Total		4739	2266

To date, 224 mink and 139 ferrets have been caught over 62 000 trap nights (each trap night represents one trap open for one night). Trapping efficiency has improved since the start of the project, and each trapper now checks 40–55 traps per day, compared with 25–35 traps at the beginning. Only 5 days have been lost due to bad weather, mostly when it was considered too dangerous to use boats to access offshore islands.

Population estimates

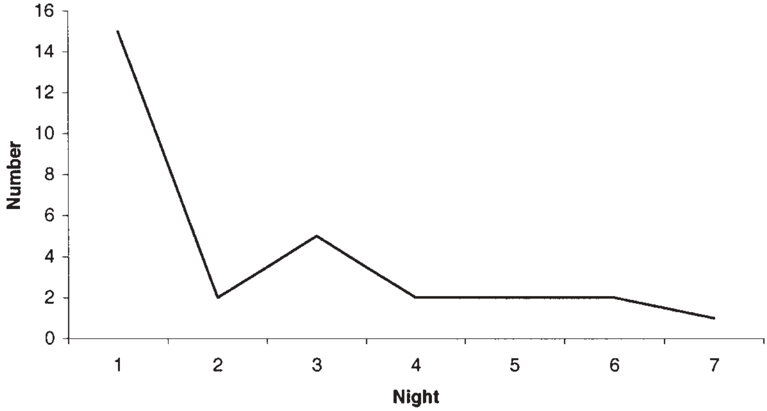
The carrying capacity for mink of habitats on the Western Isles, and within the HMP area, both appear to be substantially lower than expected from previous work (Hudson & Cox 1988). The highest densities recorded so far have been on the coast and on small offshore islands, and the lowest on inland lochs (Table 1). The total potential pre-breeding Western Isles mink population was estimated at 4739 individuals (including 2266 in the HMP area) of which over 70% were likely to be located on the coast in both cases.

Our second estimate of the actual population in the HMP area at the start of the work came out at 487 individuals (199 in South Harris and 288 in the Uists).

Trapping success over time

Trapping success so far has been strongly seasonal. Most mink were caught in autumn, when the juveniles disperse, and in spring, during the mating season (Fig. 3). This seasonal variation was somewhat exaggerated in August/September 2002 when trappers moved into previously untrapped

Fig. 4 Trapping success per night in 53 traps on two islets in the Sound of Harris which had not been trapped for 2 years (August 2002).



areas. There was no apparent difference in this seasonal pattern between the sexes; both are difficult to trap in May and June when females give birth and do not venture far from their dens. Males also appear to have reduced home ranges at this time of year (Dunstone 1993).

Preliminary experiments using dogs to actively search for sign of dens, and setting several traps in close proximity to the den entrances, have been very successful at this time of year. The differences were highly significant (line trapping success: 0.11 mink per trap night during a restricted period in May/June compared with 0.94 mink per trap night for den trapping in the same period and in similar habitat; $U = 411.0$, $P < 0.02$). Successful den trapping is especially important for females, which are judged to be almost impossible to catch on standard trap lines in early summer (Ireland 1990, quoted in Dunstone 1993; HMP data from 2002).

Trapping success in each new area declined rapidly over time, and few animals were caught after the first week. Fig. 4 shows the trapping success in 53 traps per night on two offshore islands (4.8 km^2 in area) in the Sound of Harris, which had been untrapped for the previous 2 years and had a high density of mink. No animals were trapped after the seventh trap night.

There was no clear seasonal pattern in ferret captures, although catches were very variable from month to month throughout the year (Fig. 5). Some of this variability was due to the patchy distribution of ferrets; we suspected that in months when high numbers of ferrets were caught, the trapping effort may have been concentrated in areas with high ferret density.

Use of scent gland lures

In early trials we found that commercially available mink scent gland lure produced no improvement in capture rate. A second, small-scale experiment using 30 traps over 5 nights in August 2002 (in the juvenile dispersal season) investigated the effects of baiting traps with scent glands removed from local male mink trapped during the project. Initial results suggested a significant increase in trap success: scent gland baited traps were 50% more effective than fish baited traps (total $n = 16$ mink). Larger-scale studies are now underway, which will also assess whether using scent glands of both sexes is more effective during the mating season, and whether male scent glands can be used to target adult females. The results of all the above trials are detailed by Roy et al. (unpubl. data).

Effects on bird populations

Baseline monitoring began in summer 2002, and counts were made at 97 "colonies" (ranging from 1 to 400 pairs), with combined total population estimates of 1604 pairs of arctic tern, 414 pairs of common tern, and 128 pairs of little tern (Evans & Allan 2002). These birds represent a significant proportion of the United Kingdom populations of little and arctic terns (8% and 3.5%, respectively). Sixty-four gull colonies, comprising 2404 pairs of five species, were also counted. Only one (arctic tern) colony was affected directly by mink predation in the first year; after 83 eggs were lost, the colony was deserted (although it is likely that these birds re-nested subsequently). However, the distribution of tern colonies suggests that the most successful nests are now on tiny, low-lying islets

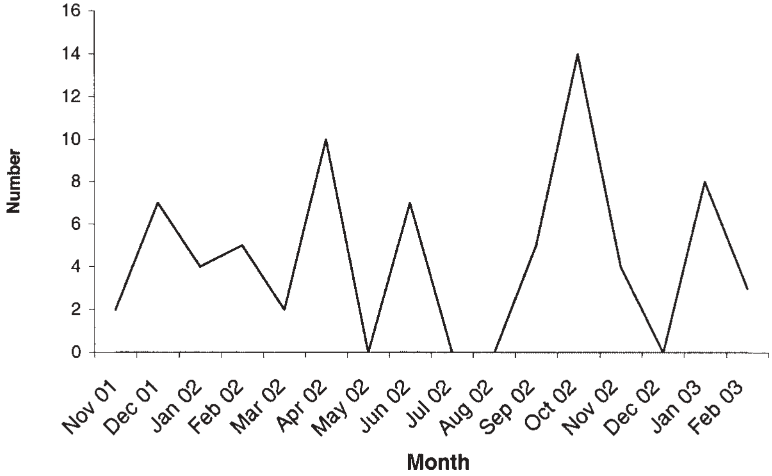


Fig. 5 The distribution of ferret catches per month.

that are prone to inundation during summer storms (Evans & Allan 2002). Further investigation will show us whether or not this is an effect of disturbance from mink.

Trials of new techniques

Use of thin layer chromatography (TLC) to identify bile acids

Detecting the presence of mink, usually by searching for scats, is crucial to assessing the success of the trapping campaign. However, previous work (Harrington et al. 1999), and HMP work so far, has shown that distinguishing mink from ferret scats is extremely difficult. However, species-specific bile acids produce unique banding patterns on chromatograms, which might allow us to distinguish between ferret and mink scats. Initial investigations using thin layer chromatography (Capurro et al. 1997; Fernandez et al. 1997) to identify the composition of bile acids extracted from scats has shown considerable promise, but we need to analyse more samples from all species to validate the technique.

DNA fingerprinting

We are also trialling the use of DNA fingerprinting to estimate the numbers of individual animals and to monitor trapping success. Preliminary work has shown that individuals can be told apart from tissue collected post mortem. Work currently in progress will calculate whether sufficient DNA can be extracted from scats to distinguish between individuals. To date, mitochondrial DNA (multiple copies per cell) has been extracted from scats, but we are still unsure if sufficient genomic DNA (one copy per cell) can be extracted. If this were feasible, then it might be possible to census the mink populations from scats in an area prior to trapping, and to compare this genetic information with samples from carcasses of animals captured subsequently.

DISCUSSION

Although it is too soon to comment on the success of the project, early indications are promising. Judging by the high capture rate in the first week of trapping in each area, mink are relatively easy to catch. We appear to have reduced numbers dramatically over much of the HMP area; in some extensive parts of it (c. 100 km^2 of South Harris), mink trapping success has declined to virtually zero. However, the small numbers of mink caught have produced difficulties for our public relations, when it appears that the project is expensive in terms of the amount of money spent catching each individual mink. It is important to calculate realistic estimates of carrying capacity for the archipelago, to improve the accuracy of forecasting the feasibility and costs of a complete eradication campaign throughout the Western Isles. Our current estimates are between 50 and 70% lower than those of Hudson & Cox (1988), and these will be refined further as more data on trapping success in different habitats are analysed. Mink were clearly well below the carrying capacity when the project commenced, probably due to previous trapping by gamekeepers and other individuals, and the relatively recent colonisation of parts of the HMP area (e.g., South Uist).

If over 70% of the population is coastal, as early results suggest, then achieving a dramatic reduction in mink numbers will be easier than was initially predicted. However, removing the last animals of a low-density population is likely to be the greatest challenge, as is the case with many eradication campaigns (Gosling & Baker 1989). Here, the use of dogs is likely to be crucial. Dogs have so far proved very successful in locating active den sites and mink sign which had gone unnoticed by trappers. The use of dogs specifically trained to search for active dens when females are breeding has been effective at a time when normal line trapping was almost completely ineffective. This variation in the work pattern will also serve to motivate field staff during periods when mink are otherwise difficult to trap.

The support of well-researched science is also crucial. For example, the use of locally-derived scent gland lures may prove very important to the success of the project. Despite the failure of commercially available lure, scent glands extracted on site have improved trapping success. This technique may be particularly useful in catching mink at low densities, when the remaining individuals may be more responsive to intraspecific olfactory stimuli.

Several important lessons have also been learned about the importance of maintaining good relationships with the public. The involvement and support of local islanders is vital, and has been much encouraged by the Community Liaison Forum. Local people can act as "eyes and ears" for the project. They have already discovered mink outside of the original HMP area, enabling the project managers to respond immediately. There is a need for continuous, open and positive communication to maintain the project's positive profile in the local community. On the other hand, local knowledge can also be misleading if it is wrong. Preconceptions about behaviour of mink must be avoided if they allow some individuals of the target species to remain unexposed to trapping, and thereby appear (wrongly) to constitute a trap-shy element in the population. For instance, if the widely held belief that virtually all mink live along the coast is incorrect, it could lead to too little trapping in inland areas, leaving behind a significant residual mink population.

It is also important to encourage innovation of new techniques and novel approaches suggested by the field staff. Several very significant developments have already emerged from them, which have been nurtured by regular feedback from the scientific and modelling side of the project.

American mink are a widely introduced alien species in Europe and South America, and some of the lessons learned here have wider applicability to other areas where introduced mink damage native wildlife. American mink are a threat to bird populations on a global scale. In Iceland, the spread of American mink has induced changes in the nesting distribution of black guillemots (*Cepphus grylle*), whose largest nesting colonies are now concentrated on inaccessible offshore islands. Other species believed to have been badly affected include water rail (*Rallus aquaticus*) and Slavonian grebe (*Podiceps auritus*) (Hersteinsson 1999). In Baltic Sweden, American mink have also eliminated many small seabird colonies, and caused the concentration of the remainder onto inaccessible islands. Species involved include herring gull (*Larus argentatus*) and razorbill (*Alca torda*) (Andersson 1999). Other species, which cannot escape to islands, are declining within the mink's established range but remain stable in other areas. These include velvet scoter (*Melanitta fusca*), red-breasted merganser (*Mergus serrator*), and black guillemot (Andersson 1999). Recent mink control experiments in Baltic Finnish islands have shown how mink removal benefits a wide range of ground-nesting (mainly aquatic) birds, especially smaller species (Nordstrom et al. 2002, 2003).

American mink also have a negative impact on several native mammal species in Europe. Within the United Kingdom there is growing interest in local mink control to protect remaining water vole (*Arvicola terrestris*) populations. In Europe, particularly in Eastern Europe and Spain, American mink pose a major threat to the remaining populations of European mink (Maran et al. 1998). Our work will add to the growing body of research on American mink in Europe. As well as providing further evidence of their detrimental effects on native wildlife, it will help to develop and refine new capture techniques. We are confident that the eradication model, which is one of the main aims of the work, will also be applicable elsewhere to help other agencies making decisions on where and when to use scarce resources to have most beneficial effect on threatened native species.

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