Forestry England

VWT Vincent Wildlife Trust

Preliminary work towards a sustainable harvesting model of pine martens in Scotland for translocations

(to supplement a long-term strategy and recovery plan for pine martens in Britain)

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Jenny MacPherson[1], Elizabeth Croose[1], Ciara Powell[2], Stephen Carter[1], Catherine O'Reilly[2]

1 Vincent Wildlife Trust, 3-4 Bronsil Courtyard, Eastnor, Ledbury, HR8 1EP
2 Waterford Institute of Technology, Waterford City, Co. Waterford, Ireland X91 K0EK

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Summary

Since 2015, VWT has been involved in pine marten translocations from Scotland for population restoration in Wales and, more recently, Gloucestershire. A primary consideration in these translocations has been to minimise the potential for negative impacts on recovering donor populations in Scotland. To this end, surveys and monitoring have been carried out to collect further data to inform the way in which current and future sustainable harvesting models are applied. Based on precautionary principles, VWT adopted a highly conservative approach to trapping and removals in the first instance. Data on indices of marten activity at donor sites to date suggest that this has proved effective, and population estimates derived from genetic analysis of non-invasively collected samples support the suggestion that only a relatively small proportion of resident animals have been removed. However, the sampling strategy could be improved to refine population estimates further and better inform the way in which donor populations are managed and conserved in the face of higher demand from other organisations in future.

Introduction

There is currently huge interest in finding 'quick-fix solutions' to reverse the loss of biodiversity which has led to a growing interest in rewilding and species translocations. Conservation translocation is the managed movement of animals or plants from one location to another to achieve a measurable conservation benefit for the population, species or ecosystem (Seddon, Strauss & Innes 2012; IUCN 2013). The term covers reinforcement, where you are adding to an existing (but often small) population; reintroduction, to restore a species to part of its natural range from which it has gone extinct; or conservation introduction, also called assisted colonisation, where the aim is to establish new populations of a species beyond what has previously been its natural range (Seddon 2010; IUCN 2013). Habitat loss and fragmentation, along with other factors, have led to population declines and local extinction for many species. Translocations are a widely used conservation tool in situations where natural recovery or recolonisation is unlikely; however, they need to have clear goals from the outset and be very carefully thought out.

After a thorough feasibility assessment and extensive community engagement, beginning in 2014, Vincent Wildlife Trust carried out three conservation translocations of pine martens from Scotland as part of the Pine Marten Recovery Programme for Wales and England (MacPherson 2018). Habitat suitability modelling was carried out for the whole of mainland Britain and the results of this and other analyses showed that central Wales had the highest suitability for re-establishing a viable pine marten population. Further potential release regions in priority order were in Gloucestershire and south-west England (MacPherson *et al*. 2014).

A total of 51 adult pine martens were released in mid-Wales from 2015-2017 where a breeding population has now established and is slowly expanding. There are a growing number of pine marten reintroduction proposals from other organisations in Britain, many of which are particularly interested in using martens as a biological control since recent studies suggested a negative impact of pine martens on grey squirrels in Ireland (Sheehy & Lawton 2014) and Scotland (Sheehy *et al*. 2018). However, these proposals, all from different organisations and partnerships, have no overarching strategy to guide the decision to translocate. Translocation should always be a last rather than a first resort, used only where natural recolonisation is unlikely, and there are many factors to consider carefully before embarking on such a solution.

VWT, SNH, NE and NRW have been working with and guiding partner organisations for some time, but now, with the increasing number of proposals, a more formal strategy document is needed to help guide both project proposals and the decision of funders and statutory agencies to grant funding and licences. VWT, in partnership with the SNCOs of England, Scotland and Wales and FE, is producing a long-term (10-year plus) strategy, outlining a recovery plan for pine martens in Britain that will have the maximum conservation benefit at a national level, with the minimum impact on donor populations in Scotland. It is important to conserve the recovering pine marten population in Scotland, as well as to monitor and facilitate natural spread and recolonisation where possible. Any future reintroductions elsewhere should be to the most optimal regions in England and Wales in priority order, and in such a way that maximises the probability of reintroduced populations establishing, spreading and ultimately linking up. These can be identified based on analyses and models of habitat suitability, as well as other factors likely to affect survival and reproduction, key parameters in the establishment and spread of reintroduced populations.

In addition to the strategy document, we need to refine current sustainable harvesting models to inform future proposals for translocating martens from donor sites in Scotland. This requires data on the likely impact so far of populations that have been harvested for VWT's translocations to Wales in 2015-2017 and the more recent, ongoing, translocations to the Forest of Dean in partnership with the Gloucestershire Wildlife Trust. Further work towards this was undertaken in March 2020 to supplement prior work that was carried out by VWT as part of the Pine Marten Recovery Project in 2015, 2016 and 2017, with genetic analyses in partnership with Waterford Institute of Technology (WIT).

A key element of successful reintroduction programmes, and the removals associated with them, is the integration of genetic management into the scientific design, in addition to an understanding of ecology and demography of the reintroduced species (Robert, Couvet & Sarrazin 2007). In addition to any impact on absolute numbers, harvesting populations can potentially cause a genetic bottleneck leading to inbreeding and loss of genetic diversity, and as a result may have hidden consequences. Therefore, the population size and genetic diversity of such populations are central points to consider when assessing impacts of removals on genetic diversity and population persistence, of both the donor and founder population (Jamieson & Lacy 2012).

Donor populations and selection method

Results of population viability analyses showed that between 30 to 40 pine martens would need to be released in an area to maximise the viability of the founder population (Bright & Halliwell 1999), MacPherson 2014, *unpubl.data*). It is recommended that, where sufficient stock is available, wild caught animals are used for reintroductions (Griffiths & Pavajeau 2008). These generally show higher survival and better adaptation to the new environments than captive bred animals and this is particularly true of carnivores (Jule, Leaver & Lea 2008). Source populations should show characteristics based on genetic provenance, morphology, physiology and behaviour that are appropriate in comparison with remaining wild populations. Animals sourced from areas with similar prey species, competitors, predators and habitats may demonstrate higher rates of post-release survival and reproduction (Aber *et al*. 2013). A published study comparing the haplotype composition of historical and current pine marten populations in England, Scotland and Wales found no differences between the main haplotype of contemporary (post-1950) populations across the UK (Jordan *et al*. 2012). Therefore, the increasing and expanding population of pine martens in Scotland is the most suitable source of animals for translocations to England and Wales. However, this must be carefully managed to avoid negative impacts on recovering Scottish populations.

Regions likely to contain suitable pine marten donor populations were originally identified on the basis of woodland cover, altitude and known length of occupancy by martens. These are shown in figure 1. Intensive harvesting of a population with a low rate of increase, in a changeable environment can lead to its extinction or severe depletion (Lande, Engen & Saether 1995). Pine marten populations can be susceptible to overharvest (Helldin 2000), therefore the effects of removing individuals from source populations must be monitored. To safeguard viable populations of pine martens throughout their range, a long-term strategy and recovery plan should include carefully considered goals, effective monitoring of population changes and tools to ensure that harvesting of donor populations is sustainable. Timing of removals is also key as there is a higher risk that removing animals in late winter would be additive to other winter mortality and have a greater impact on the donor population.

The donor populations identified by VWT were those within large forest blocks where the removal of between two and four individuals per forest in late summer (at the end of the breeding season) is least likely to have an impact on population viability.

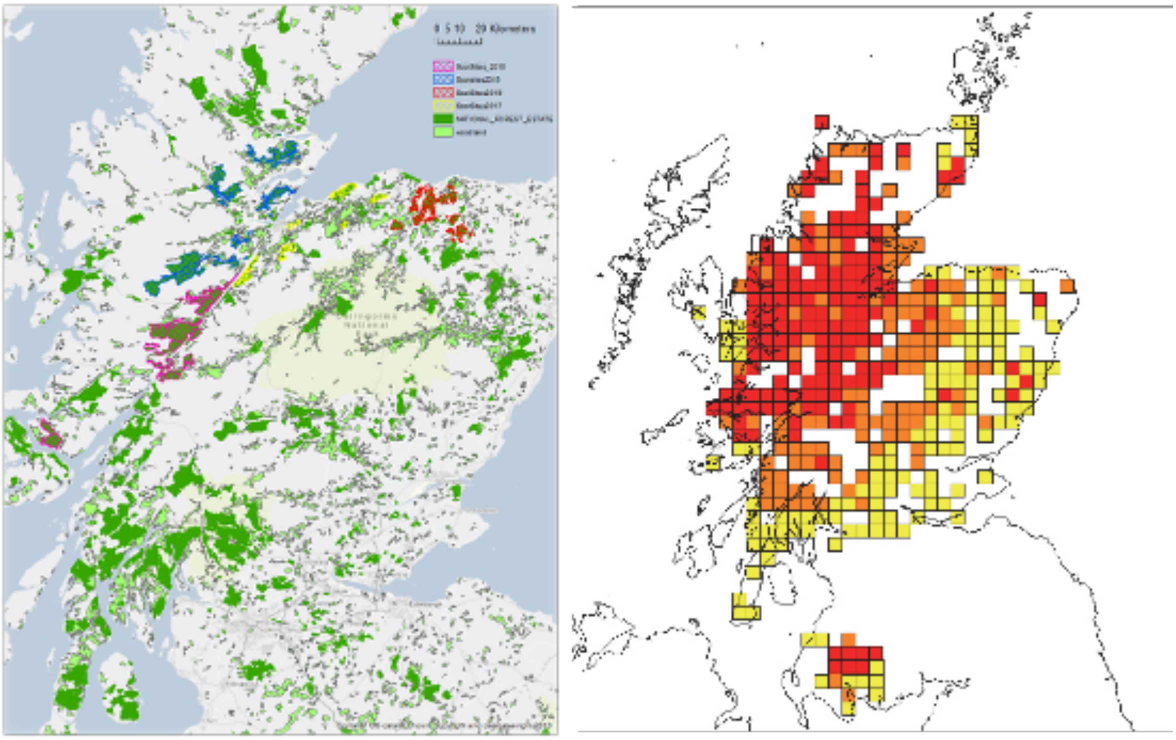

Figure 1 Left: Forestry and Land Scotland source sites used for pine marten translocations to Wales in 2015 (blue), 2016 (purple) and 2017 (yellow) and to Gloucestershire in 2019 (red). Right: Distribution of the pine marten in Scotland, comprising records collected from 1980 to 2012. Positive hectads from the 1980-1982 distribution survey (Velander 1983) are shaded red; positive hectads from the 1994 distribution survey (Balharry *et al*. 1996) are shaded orange; and positive hectads from the 2012 Expansion Zone Survey (Croose, Birks & Schofield 2013) are shaded yellow (reproduced from Croose *et al*. 2014).

Pine martens have established on the Black Isle relatively recently in comparison to the other proposed source populations. However, the lowland mixed woodland on the Black Isle is very productive habitat and likely to support a high density of martens now that they have been established there for more than 30 years. Additionally, although it is a peninsula and not an island, the Black Isle is only connected by a very narrow (8km) strip of land. This may have the effect of limiting dispersal to the 'mainland' and therefore maintain pine marten populations at artificially high numbers. Anecdotal evidence suggests that widespread feeding of martens on the Black Isle (either directly or indirectly from bird feeders) is supporting the high densities and, indeed, many scats collected here contain peanuts and other evidence of a human supplemented diet.

An age-structured population model to examine the numerical effects of removal on source populations of pine martens showed that two years after 15% of adult animals were removed, there was a more than 80% probability that populations would have returned to their initial size. However, even if 25% of the population was removed, there was a high (>90%) probability that five years after the removal the population would have returned to its initial size (Bright & Halliwell 1999). With this in mind, and based on the precautionary principle, at present it would not be prudent to re-trap at sites where animals were removed for translocations to Wales in 2015, 2016 and 2017 until at least five years after they were trapped. This would mean that the sites that were trapped in 2015 (blue in figure 1), could potentially be trapped again in autumn 2020, subject to assessment and discussion with SNH and Forestry and Land Scotland (FLS), the landowner.

In addition to scat surveys and habitat assessments at each of the proposed donor sites, informal consultations were carried out with local stakeholders and residents to ascertain if there were any concerns about a small number of animals being removed from the area, or any other projects, research or businesses (i.e. commercial hides or tourism enterprises) that might be impacted. As a result, VWT has avoided trapping in some areas which are in the proximity of businesses or people who enjoy watching and interacting with their local martens.

VWT has always proceeded on the precautionary principle of only removing a maximum of four martens from any one forest, in autumn. The territories left vacant by these removed animals should be filled very quickly by dispersing juveniles or non-territory holding martens. As martens are territorial, it is suggested that leaving untrapped 'refugia', at least twice the size of a mean marten home range, may protect a population reservoir from which trapped areas will quickly recolonise (Strickland 1994). All trapping and removal is only carried out in FLS woodlands, so it is likely that there are further sources of recolonisers in privately-owned woodland adjacent to each of the donor sites. Initially the maximum number of pine martens taken from each source site was proposed based on a combination of the following: indices of marten activity from scat surveys carried out in the preceding March (VWT unpubl. data); and conservative estimates of the number of adult martens present. The latter were derived from correlates of marten density (prey indices and forest cover) and woodland area (Bright and Halliwell 1999).

The sites shown in figure 1 were selected in preference to some of the other forest blocks north of the Great Glen because, whilst the more northerly sites (such as those around Loch Shin) and those to the west around the Kyle of Lochalsh have a longer, or continuous, history of occupancy by martens, logistically they would be more challenging, and necessitate a much longer journey by road for those animals that were trapped and translocated, with associated welfare issues.

Method

At each potential source site, scat surveys were carried out in March 2015, 2016, 2017 and 2020. Scat surveys were conducted along paths, rides and tracks within woodland at a density of approximately one 1.5km transect per tetrad (4km^2) of woodland. Experienced surveyors only recorded and collected scats that they had high confidence were from pine marten, based on size, morphology and smell. Scats were collected and placed into a separate plastic zip-locked sample bag with a unique identification number and a 10-figure grid reference. Scat density was recorded, and all samples were frozen and stored. Thirty and 22 animals were trapped in 2015 and 2016, respectively, of which 20 animals were removed for translocation in 2015 and 19 were removed in 2016. Hair samples were taken from all trapped animals and stored dry in Ziplock bags.

A second scat survey (post-translocation) was conducted at the 2015 and 2016 removal sites, in spring 2016 and 2017, respectively. Scat density was recorded, and all samples were frozen. A short project (funded by PTES) was carried out at Waterford Institute of Technology in 2017 to extract and analyse DNA from these scat samples, and hair samples that had already been collected from trapped and released animals (Powell, MacPherson & O'Reilly, 2017 unpubl. report). Samples were genotyped using a panel of microsatellite markers to identify individuals. This preliminary work tested methods for the determination of an accurate population estimate which it was hoped would enable the calculation of a maximum harvestable number. A minimum number alive was produced for each site and genetic diversity was investigated in pre- and post- removal populations.

The 2015 donor sites were then resurveyed in March 2020 (5 years post-harvest), using the same protocols.

Results

A total of 410 scat samples were collected from 54 transects within the prospective trapping areas in Scotland during the initial surveys in March 2015, and 153 scat samples were collected across 20 transects in March 2016. Thirty hair samples were also collected in 2015 and 22 in 2016 from translocated animals and animals which were trapped but not selected for translocation so were released again at their capture site. DNA was extracted from 150 of the initial 410 scat samples collected. Samples most likely to yield sufficient DNA were with samples being selected based on field description (i.e. high confidence of pine marten and fresh). Genotyping was completed for 105 scat samples and fifty hair samples. One hundred and ten unique individuals were identified, 52 females and 58 males. The mean number of alleles per locus detected in both post-removal populations was 3.0, which was not significantly lower than those in the two pre-removal populations ($U = 0$, $z = -0.894$, $p > 0.05$). The mean expected heterozygosity was 0.512 and 0.493 in the post-removal populations and 0.548 and 0.533 in the pre-removal populations. Compared to the pre-removal populations, expected heterozygosities were not significantly reduced in the post-removal populations ($U = 0$, $z = -0.894$, $p > 0.05$).

Pre-harvesting population size of the sites trapped in 2015 and 2016 was investigated using CAPWIRE (Miller, Joyce & Waits 2005). CAPWIRE yielded estimates of 192 (95% CI = 99 -502) for the pre-removal population in year 1 and 191 (95% CI = 102 -311) for the pre-removal population in year 2.

Due to limited resources, further DNA analysis has not yet been carried out on the sites that were trapped in 2017 or 2019, although scat surveys were conducted in March 2020, using the same protocols as those for the other donor sites. Scat samples have been collected and archived.

The density of scats (mean/km surveyed) for each site pre- and post-harvesting is shown in Table 1. There was no significant difference between mean scat density pre-harvest and 1 year post-harvest (Wilcoxon signed ranks statistic=35.02; n=12, p=0.75), or 5 years post-harvest (Wilcoxon signed ranks statistic=3.02; n=6, p=0.12).

Table 1 Mean no. of scats/km surveyed at each site.

Site	Survey year (trap year)	$\bar{x}$ scat density pre-harvest (March)	$\bar{x}$ scat density 1 year post-harvest (following March)	$\bar{x}$ scat density 5 years post-harvest (March)
Strathglass	2015	5.4	5.6	6.2
Glenurquart	2015	9.0	14.3	1.5
Boblainy	2015	2.0	3.2	1.8
Black Isle	2015	14.1	8.9	6.7
Contin	2015	6.2	6.0	5.8
Strathgarve	2015	9.7	5.3	5.3
Morangie	2015	9.0	11.7	-
Glen Garry	2016	5.5	6.9	-
Glen Moriston	2016	8.5	5.7	-
Inchnacardoch	2016	4.3	1.4	-
Leanachan	2016	4.1	6.2	-
Morvern	2016	7.3	7.0	-
Culbin	2017	4.8	Not trapped	Not trapped
Culloden/Assich	2017	4.1	n/s	-
Farigaig	2017	4.4	n/s	-
Darnaway (Newtyle)	2017	4.7	n/s	-
Daviot	2017	4.2	n/s	-
Bin Forest	2019	9.5*	3.0	-
Aultmore	2019	5.0*	8.0	-
Whiteash/Ordieq-uish	2019	2.3*	6.5	-
Teindland/Orton	2019	3.0*	7.5	-
Balloch	2019	n/s	6.5	-
Archiestown	2019	21.0*	Not trapped	Not trapped
Ben Aigan	2019	4.0*	Not trapped	Not trapped

(*surveys carried out in July 2019)

Scat density per transect was highly variable, as shown in figure 2. This is likely due to the effects of current or very recent felling and therefore disturbance in some parts of the forests that were surveyed. Transects were pre-selected from Ordnance Survey maps with no prior knowledge of active felling plans. Some transects that were re-surveyed which had, in previous surveys, had high numbers of marten scats present were negative, whereas others were positive. Marten home ranges are dynamic across relatively large areas and, for this reason, the mean density of scats over time across a wider forested block (shown in table 1) is likely to be a more accurate index of marten activity than that on specific transects, tracks or paths.

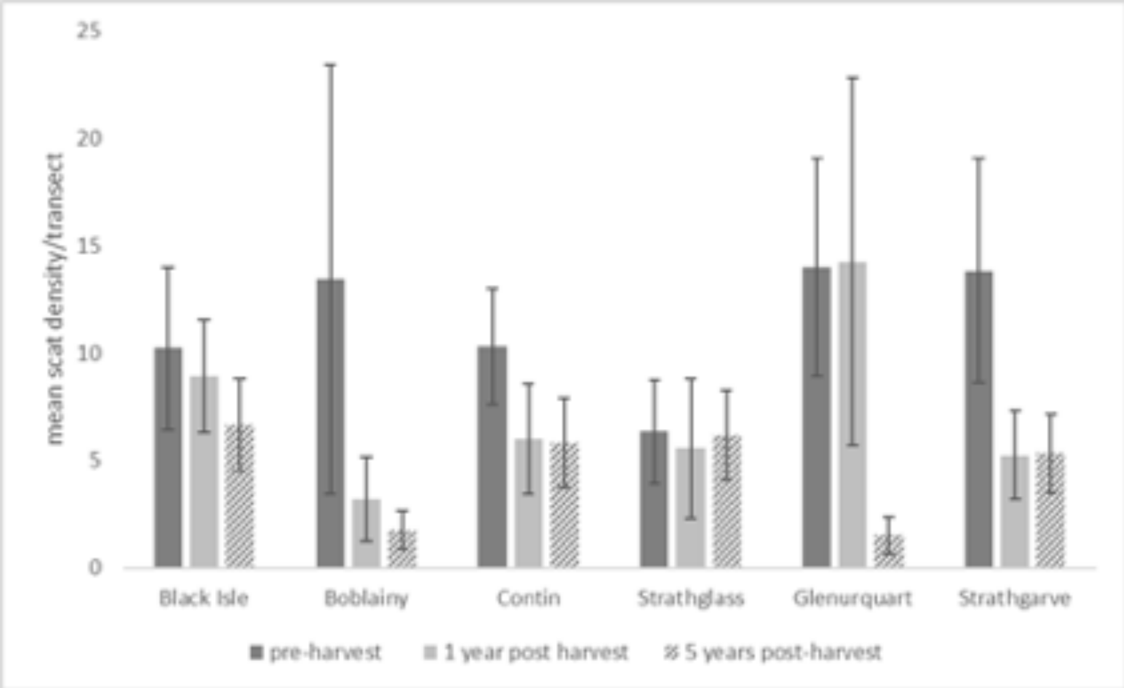

Figure 2 Mean scat density per transect pre-harvest, 1 year and 5 years post-harvest at sites trapped in 2015.

Catch Per Unit Effort (CPUE) is often used as an index of abundance, and numbers modelled based on the assumption of proportionality, although the validity of this assumption is uncertain (see review in Harley, Myers & Dunn 2001). We plotted scat density (an index of activity) against CPUE to see if there was any relationship (figure 3). The two indices were only very weakly correlated in our dataset, and the relationship was not significant (p=0.18, Spearman's R=0.311, df=18).

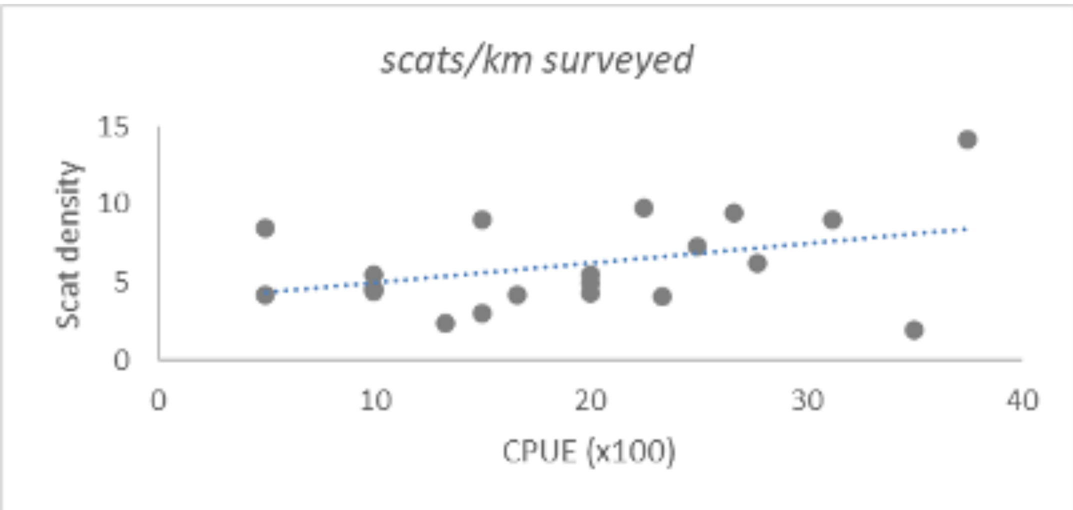

Figure 3 Scatter plot of scat density against Catch Per Unit Effort (CPUE).

Discussion

Preliminary work conducted here using scat surveys as an index of marten presence and genetic analysis of scats and hairs, indicate that the conservative harvesting approach undertaken to date has been successful in minimising the impact on the donor populations. However, the sampling strategy could be improved to better inform how donor populations are managed and conserved as demand for source animals increases.

Our data showed that there was no significant loss of genetic diversity in the post-removal populations harvested in year one or year two. The slight reduction in both the number of alleles and expected heterozygosity may be accounted for by the variation in sampling effort (scat survey and live capture vs. scat survey alone). In future, increased survey effort in the removal areas may result in findings of increased genetic diversity.

It is encouraging that there was no significant difference detected between the mean density of scats pre- and post-harvest, one year and five years after the initial trapping and removal of martens. However, there was high variability between transects in any given year, and this method has its limitations. Scat surveys were carried out in March to confirm the minimum presence of pine martens within proposed donor sites, and to look at relative indices of activity before the breeding season. Seasonal variation may influence the results of pine marten scat surveys. It has been observed that scat density (scats/km) varies greatly from month to month, being more than 100 times greater in July than in January (Velander, 1986). This fits the prediction that marking activity should be highest during the summer (July/August), when adults are mating, and the population is increased by the presence of newly independent young. Conversely, pine marten activity is greatly reduced during the winter months (Zalewski, 2000). This means that surveys in March will likely underestimate, rather than overestimate marten activity. However, the objective of this work was to compare relative, not absolute, densities of martens pre- and post- harvest.

Whilst there is not a linear relationship between the number of pine martens and scat abundance, as was once thought (Lockie, 1964), it has been found that scat density is higher in areas of higher pine marten abundance (Sheehy *et al*., 2014). Other factors that are known to affect scat detection, deterioration and deposition rates, include a range of environmental and ecological conditions. The detectability of pine martens may be reduced by adverse weather conditions during and prior to surveys. Heavy rain may temporarily reduce marten activity (and therefore scat deposition rates) and also increase the rate at which scats deteriorate. On uneven, heavily vegetated paths or those with dark substrate, the detectability of scats is also likely to be reduced as this may reduce their visibility, affect deposition rates and also provide favourable conditions for scat and DNA deterioration through the action of microbes and scat-predating invertebrates, such as slugs. A study by McHenry *et al.* (2016) found that vegetation height and cover had the greatest (negative) effect on the probability of pine marten detection. However, the occurrence of rain in the two days prior to and during surveys did not affect estimations of detectability. Detection probabilities were positively related to transect width because, it is suggested, pine martens may be more likely to scat on wider forest paths, as marking more prominent features may provide more effective olfactory communication with conspecifics.

The density of martens estimated using prey indices and forest cover as correlates of marten density (Bright and Halliwell, 1999) were compared with those derived from marten home range data for two areas: Strathglass (Balharry, 1993) and Strathrusdale (Caryl, 2008). The estimates arrived at by the two different methods for these sites were not significantly different. However, whilst using indices may be sufficient to look at relative changes within sites between years, it cannot be used to accurately compare sites or to monitor changes in numbers or genetic health of populations.

Advances in molecular methods mean that it is now possible to use non-invasive methods to acquire genetic data to inform conservation decisions. We were able to make some useful inferences about the impact of harvesting at donor sites in the first instance. Population estimates derived from genetic analysis of these samples support the suggestion that only a relatively small proportion of resident animals had been removed. However, there are limitations to using scat and hair samples collected, as was necessitated here, on single sampling occasions.

The PVA model on which the initial, conservative harvesting protocol was based, predicted that two years after 15% of adult animals were removed there was a more than 80% probability that populations would have returned to their initial size. However, even if 25% of the population was removed, there was a high (>90%) probability that five years after the removal the population would have returned to its initial size (Bright & Halliwell 1999). The limitations of harvesting models are that they require accurate population estimates in order to be implemented (and tested) effectively.

Our pre-harvesting population estimates produced by CAPWIRE, using data from collected scat and hair samples, had large 95% confidence intervals. Nevertheless, based on these, the 20 and 19 animals removed in 2015 and 2016 represent a maximum of 20% and 18% of the population, based on the lowest end of the confidence interval, or 10% in both years based on the estimate. However, these are percentages of the total population, and an unknown proportion of those will be juvenile and sub-adult animals, therefore the percentage of adult animals removed will be higher. Juvenile to adult ratios in marten populations vary from year to year, depending on abundance of food resources which affects fecundity as well as recruitment (i.e. (Flynn & Schumacher 2000)). The impact of removing adults, particularly adult females, is likely to have a higher impact on donor populations than that of removing adults and sub-adults. However, this must be balanced against the benefits of translocating only adult animals of breeding age to increase the chances of successful reintroduction. It should also be noted that the current harvesting model does not incorporate any changes in population productivity (i.e. female fecundity or recruitment rate) following removal of pine martens. This may be affected positively, as a result of reduced intra-specific competition, or negatively if removals disrupt territorial behaviour.

It is recommended to collect 2.5 to 3 times as many samples as there are individuals for population estimation using non-invasive genetic sampling surveys (Solberg *et al*. 2006). In our preliminary study the ratio of collected samples to estimated population size was 2.03. The CAPWIRE program recommends a recapture rate of 2 to 2.5 per individual to yield an estimate in the range of 10% to 15% from the real population size. The recapture rate in this study ranged from 1.12 to 1.79 across the sampled populations resulting in very wide confidence intervals. The low recapture rate suggests that scat surveying and live capture is not sufficient for population estimation in this case. Previous pine marten population studies using hair tube surveys have produced higher recapture rates (2.33 obs./ind.; (O'Mahony *et al*. 2017) and studies using both hair tubes and scat surveys have produced recapture rates as high as 11 obs./ind. (Croose et al. 2016). While CAPWIRE software allows for multiple detections of individual animals within the same sampling session it would be advised to conduct multiple survey sessions to obtain the required number of recaptures. Further surveying will be required to achieve a higher confidence population estimate and determine whether or not the removal of the pine marten at these sites will have long-term effects on the integrity of the populations.

Further recommendations: It is suggested that a rigorous, cost effective monitoring protocol be established to monitor medium-term impact on donor sites, building on the preliminary work presented here. A combined sampling approach comprising hair tubes and scats following the methods of Croose *et al*. (2019) has been shown to be effective at detecting a significant proportion of individuals. Hair tubes yielded the highest number of observations per individual ("recaptures") which, combined with scats, resulted in the population estimate with the smallest 95% confidence interval. VWT are currently designing such a protocol which, subject to funding, could begin as early as 2021.

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