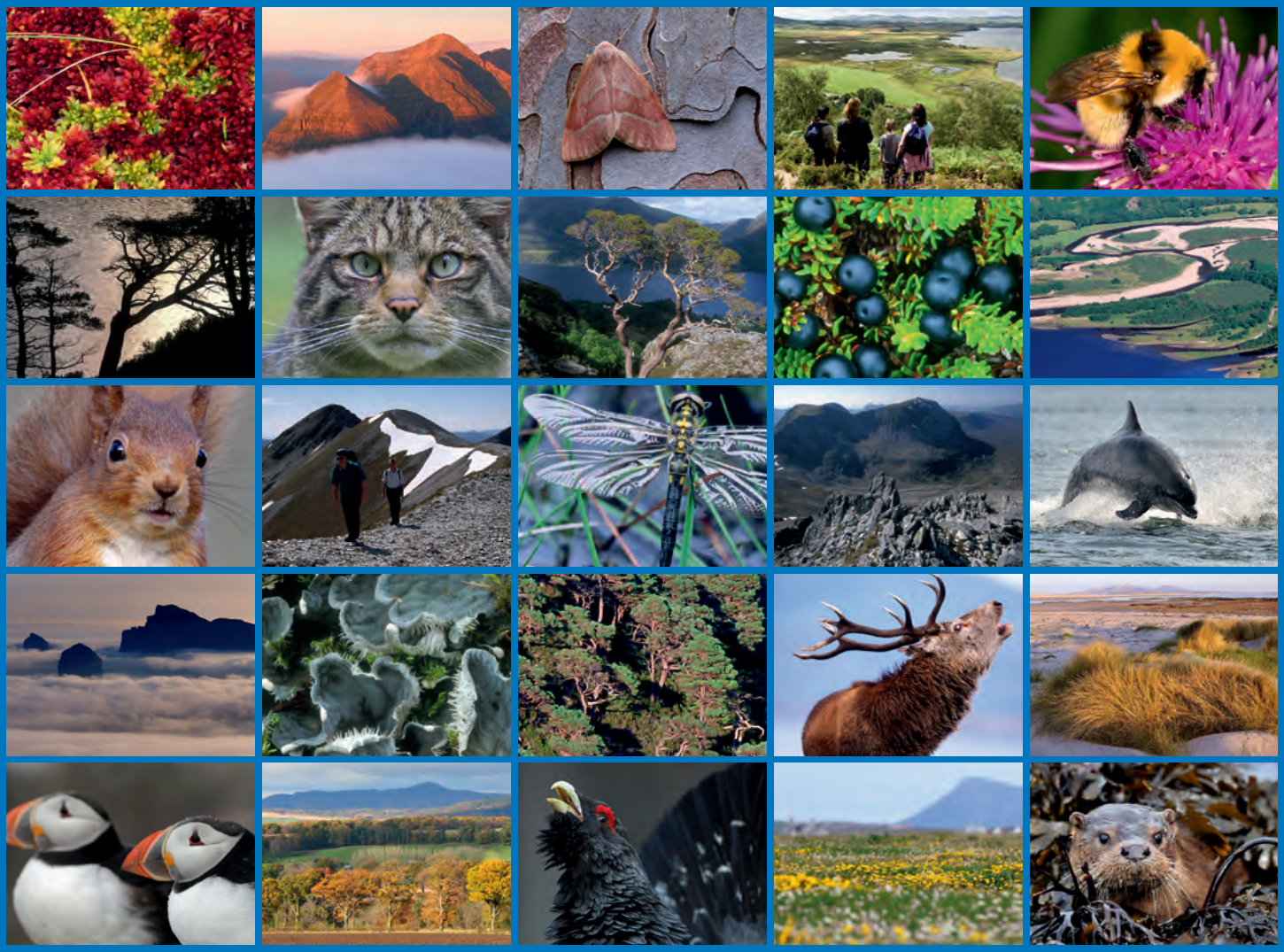
Scottish Natural Heritage
Commissioned Report No. 740

Distribution of the pine marten (*Martes martes*) in southern Scotland in 2013



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COMMISSIONED REPORT

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Distribution of the pine marten (*Martes martes*) in southern Scotland in 2013

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COMMISSIONED REPORT

Summary

Distribution of the pine marten (*Martes martes*) in southern Scotland in 2013

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Keywords

Pine marten; survey; southern Scotland.

Background

This report follows on from a pine marten *Martes martes* Expansion Zone Survey conducted in 2012 (Croose *et al.*, 2013), which provided information on current patterns of pine marten distribution in Scotland following population recovery and range expansion since the 20th century. The 2012 survey confirmed that the pine marten's range has spread from the Highland stronghold documented by surveys in the 1980s (Velander, 1983) and 1990s (Balharry *et al*., 1996) and the population has re-colonised many southern and eastern parts of its former range in Scotland.

The current survey encompassed areas of southern Scotland that had not previously been surveyed: this comprised areas south of the Central Belt to the Scottish/English border, excluding those parts of Dumfries and Galloway that were included in the 2012 survey. The survey methodology involved surveying 1km transects in woodland for pine marten scats (faeces), using DNA analysis to confirm their species of origin. Records of pine martens were also collected from other sources in addition to the field survey.

Main findings

- Pine marten scats, verified via DNA analysis, were found in five (4%) of the 117 hectads searched during the field survey.
- An unusually high proportion (61%) of scats was not determined to species level by DNA analysis. This is likely to have resulted in the occurrence of 'false negatives', whereby experienced surveyors believed pine marten scats were collected but identification was not confirmed by genetic analysis.
- Recent pine marten records, provided by recording and conservation organisations and naturalists, were collected from 13 hectads (11% of hectads) within the survey area.
- Pine marten presence was not detected in 97 hectads (83% of hectads surveyed) within the survey area.
- Pine marten presence was confirmed at four widely-spaced sites in southern Scotland and appears to be centred on three areas: immediately south and west of Glasgow; the Upper Tweed Valley; and in Annandale and Eskdalemuir in eastern Dumfries and Galloway.

- Pine marten populations in southern Scotland are likely to have originated from both natural spread from the core population and translocations and releases.
- It is likely that pine martens will re-colonise the majority of suitable habitats in southern Scotland over time.

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Field surveys were undertaken by David Bavin, Johnny Birks, Natalie Buttriss, Elizabeth Croose, Tim Hodgetts, Laura Kubasiewicz, Hilary Macmillan, John Martin, Henry Schofield, Emma Sheehy and Bridgit Symonds. Special thanks are due to those who completed fieldwork during the unseasonal 'heat wave' in July 2013. Additional help was provided by scat detection dogs Dooley and Zella.

DNA analysis of scats was undertaken by Catherine O'Reilly and Edel Sheerin at Waterford Institute of Technology, Ireland.

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1. INTRODUCTION

1.1 Background

This report describes a survey of pine marten *Martes martes* distribution in parts of southern Scotland in 2013. It follows on from a wider-scale pine marten distribution survey conducted in 2012 (Croose *et al.,* 2013), which provided information on current patterns of pine marten distribution elsewhere in Scotland, including parts of the south-west (see section 1.2 below for a full review of that survey's findings). Species monitoring is important for producing reliable status assessments to aid informed management and policy decisions for conservation (Yoccoz *et al.,* 2001).

The pine marten is a medium-sized mustelid and one of six members of the weasel family native to Scotland. It is well-adapted to three-dimensional habitats and predominantly inhabits woodlands, where its exceptional climbing ability allows it to occupy arboreal den sites and escape from predators such as the red fox *Vulpes vulpes.* The pine marten is an opportunistic generalist and its diet includes small mammals, notably field vole *Microtus agrestis*, invertebrates, fruit, small birds and carrion.

The pine marten population in Scotland is recovering following a severe historical decline. Once one of the most numerous and widespread carnivores in Britain during the Mesolithic (Maroo & Yalden, 2000), extensive anthropogenic woodland clearance for agriculture and persecution associated with trapping for fur and predator control by gamekeepers led to a widespread decline of the pine marten (Langley & Yalden, 1977). The distributional nadir of the species occurred during the early 20th century, when the species became restricted to the north-west Highlands and isolated parts of England and Wales (Langley & Yalden, 1977), where rocky, mountainous landscapes provided alternative three-dimensional habitat features offering a refuge for pine martens at a time of low woodland cover (Webster, 2001). Reductions in persecution pressure, aided latterly by the legal protection afforded to the species in 1988, and reforestation resulted in a slow recovery and range expansion by the pine marten in Scotland through the 20th century (Croose *et al.,* 2013). Pine martens persist in low numbers in restricted parts of England and Wales but the species remains very rare here and there is no convincing evidence of natural recovery south of the Scottish border (Strachan *et al*., 1996; Birks & Messenger, 2010).

The early stages of the pine marten's recovery in north-west Scotland from the late 1920s onwards were documented by Lockie (1964). Subsequently, scat-based distribution surveys undertaken in 1980-1982 (Velander, 1983) and in 1994 (Balharry *et al.,* 1996) confirmed that the species' range had expanded southward and eastward from the north-west Highlands into parts of central and eastern Scotland. A full review of these surveys is summarised in Croose *et al.* (2013).

1.2 The 2012 Expansion Zone Survey (Croose *et al*., 2013)

This survey was focused on a targeted 'Expansion Zone' area that was broadly defined as those hectads (10km x 10km squares of the national Ordnance Survey grid) located beyond the formerly recorded pine marten range identified in the previous distribution survey in 1994 (Balharry *et al.,* 1996). This area covered parts of eastern Caithness, Moray, Aberdeenshire, Angus, mid and southern Argyll, Perthshire, Stirlingshire and the Trossachs, Fife and much of Dumfries and Galloway. The main survey methodology comprised searching for pine marten scats (faeces) in one 1km transect in each hectad. Molecular techniques were used to extract DNA from scats in order to determine their species of origin. Alongside the field survey, recent verified records of pine martens were collected from a variety of sources, including Local Biological Record Centres, statutory and voluntary wildlife organisations, universities and naturalists.

The 2012 survey demonstrated that pine marten range expansion had continued into the 21st century and confirmed that the species had re-colonised parts of its former range, including vice counties Sutherland and Caithness, Moray, Banff, parts of Aberdeenshire and Kincardineshire, West Perth, Mid Perth, East Perth, a limited western area of Angus and Fife, Stirlingshire, parts of Dunbartonshire, Main Argyll and into Kintyre. The reintroduction of martens into the Galloway Forest in the early 1980s (Shaw & Livingstone, 1994) has resulted in an established population, although range expansion from the release sites has been limited compared with the core population. Pine martens have continued their natural colonisation of the Isle of Skye and are now present on the Isle of Mull apparently as a result of inadvertent translocation (Solow *et al.,* 2013). Figure 1 illustrates hectads recorded as positive for pine marten in the 2012 survey (Croose *et al.,* 2013); 1994 survey (Balharry *et al.,* 1996) and the 1980-1982 survey (Velander, 1983).

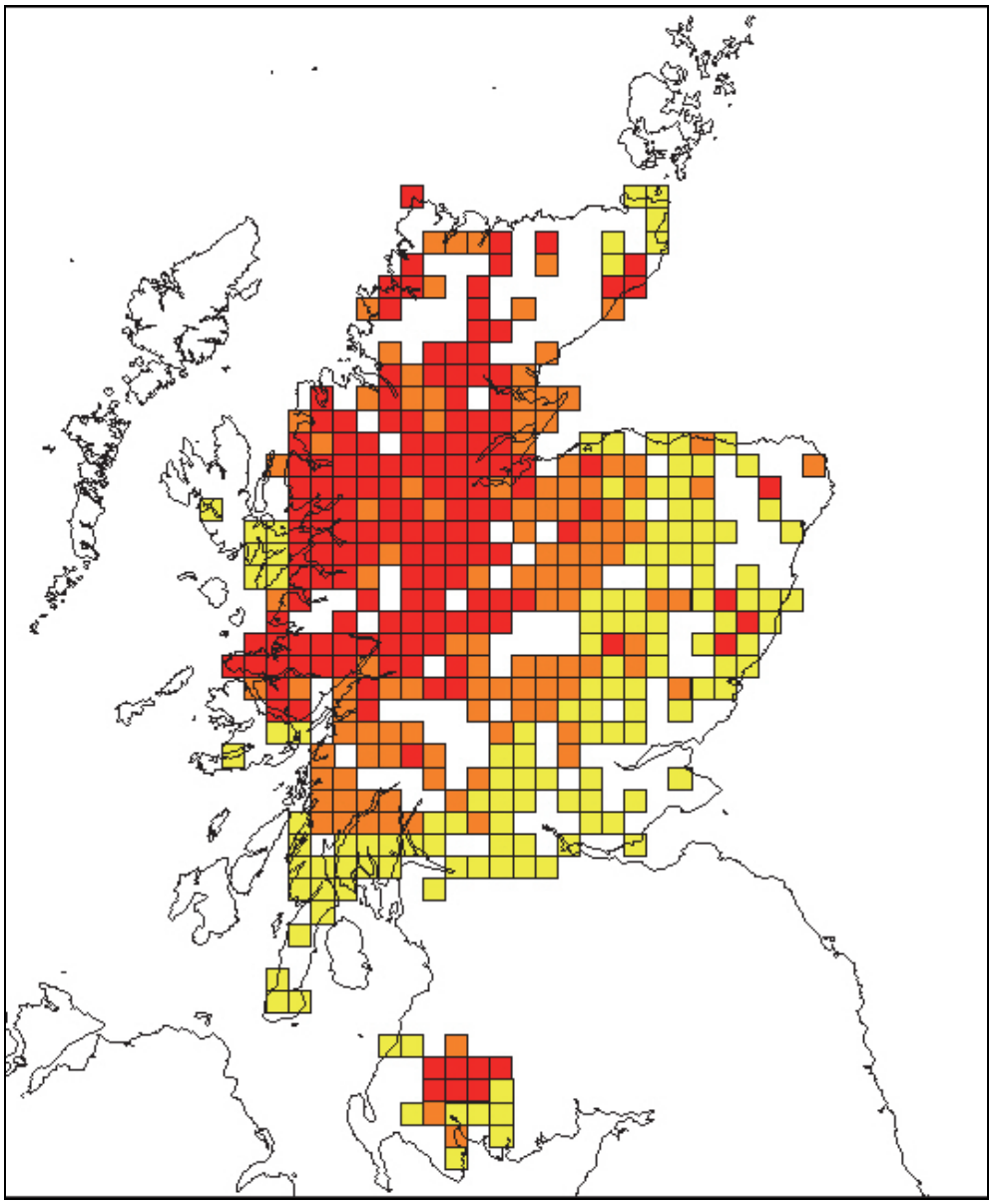

Figure 1. Distribution of the pine marten in Scotland, comprising records collected from 1980 to 2012. Positive hectads from the 1980-1982 distribution survey (Velander, 1983) are shaded red; positive hectads from the 1994 distribution survey (Balharry et al*., 1996) are shaded orange; and positive hectads from the 2012 Expansion Zone Survey (Croose* et al*., 2013) are shaded yellow. Based upon Ordnance Survey material with the permission of the Controller of HMSO © Crown Copyright (2013) Licence no. 100017908.*

1.3 The history of pine martens in southern Scotland

Langley & Yalden (1977) suggested that the pine marten became extinct in most of southern Scotland (including vice counties Roxburghshire, Berwickshire, Selkirkshire, Dumfriesshire, Kircudbrightshire, Wigtownshire, East Lothian, Midlothian, West Lothian, Peeblesshire, Lanarkshire and Renfrewshire) between 1800 and 1850. The pine marten is reported to have remained in Ayrshire for longer, until 1878, although subsequent records were reported in Ayrshire between 1960 and 1970 (Corbet, 1971, cited by Langley & Yalden, 1977). Martens were also reported in Dumfries and Galloway in the early and mid 20thcentury; Lockie (1964) mentioned one authenticated marten record from the Stranraer area in the 1920s. Shaw & Livingston (1994) mention sightings recorded on the Hoddom Estate (by Dumfries) and Laurieston Forest (by Gatehouse of Fleet) in the 1970s. Langley & Yalden (1977) suggested that 'a small colony may therefore have survived in the Southern Uplands.'

In 1980 and 1981, 12 pine martens, trapped in western Inverness-shire, were released at two sites in Galloway Forest (Shaw & Livingston, 1994), where a population subsequently became established.

In neighbouring parts of northern England, pine martens persisted in restricted areas including Kielder Forest and the Cheviot Hills during the 20th century, with records of pine martens during the 1990s in Northumberland and Cumbria, in close proximity to the Scottish border (Birks & Messenger, 2010). Notably, a pine marten scat, verified via DNA analysis, was found in Kidland Forest in the Cheviot Hills in 2010 (VWT, unpublished data), just 7km from the Scottish border.

1.4 Recent records of pine martens in southern Scotland

There is a growing body of anecdotal evidence that pine martens are present in parts of southern Scotland beyond the Galloway Forest population, yet detailed information on their distribution and status in the area prior to this survey was lacking. The 2012 Expansion Zone Survey indicated that pine martens now occur at some sites within the Central Belt, with some evidence suggesting martens may have already begun to spread further southwards (Croose *et al.,* 2013). Notably, a pine marten scat was found on a Scottish Wildlife Trust nature reserve in Cumbernauld, North Lanarkshire in 2012 (Croose *et al.,* 2013), followed by images of a pine marten captured on a camera trap on the same reserve in 2013 (D. Clark, pers. comm.) and records of martens near Twechar in 2013 (C. Smith, pers. comm.). A pine marten carcass was recorded in Clyde Muirshiel Country Park in 2002 (Croose *et al.,* 2013), and a pine marten road kill was found in Bishopton in 2013, indicating that martens are spreading south of the River Clyde.

In the Scottish Borders, 14 pine martens, rescued as abandoned/orphaned kits from the Highlands and rehabilitated by the Scottish Society for the Prevention of Cruelty to Animals (SSPCA), have been released in forestry near Innerleithen since 2007 (C. Seddon, pers. comm.). These releases have not been undertaken in consultation with SNH. Recent sightings in the area suggest that these animals are still present and may have established a breeding population. Occasional sightings of martens have also been reported from the vicinity of Hawick, Denholm and Jedburgh. Recent records of pine martens in Dumfriesshire (outwith Galloway Forest) have been documented in the County Mammal Reports for Dumfriesshire, Kirkcudbrightshire and Wigtownshire (Riches, 2010; 2012).

1.5 Survey aim

The aim of the survey was to provide reliable information on current patterns of pine marten distribution in southern Scotland following on from the 2012 Expansion Zone Survey.

A reliable assessment of the status of pine martens in southern Scotland was necessary in order to confirm or refute recent anecdotal evidence of martens in parts of southern Scotland

resulting from releases of animals. This evidence is particularly pertinent given the somewhat limited range expansion of the reintroduced marten population in the Galloway Forest since its inception over 30 years ago (Croose *et al*., 2013). Furthermore, it cannot be assumed that the core population will spread readily through the Central Belt, thus any evidence of pine marten presence south of the Central Belt could be significant for future re-colonisation of southern Scotland and the potential for natural re-colonisation of northern England in the foreseeable future.

Information on pine marten status and distribution in southern Scotland was further required to predict where future conflicts involving the species may occur and to allow production of an updated Scottish distribution map for the pine marten.

1.6 Terminology within the report

Southern Scotland

We define southern Scotland as the area south of the Central Belt to the English border, encompassing Ayrshire, much of South Lanarkshire, East Lothian, Dumfries and Galloway and the Scottish Borders.

The Central Belt

We define the Central Belt as the highly industrialised and populated area largely defined by the M8, M80 and M9 motorways, stretching from and including Greenock and Glasgow in the west, Edinburgh and Falkirk in the east and Stirling in the north.

2. METHODS

2.1 Definition of survey area

The targeted survey area covered the zone mainly south of the Central Belt to the Scottish/English border, which had not been surveyed during 2012. This area encompassed vice counties Roxburghshire, Berwickshire, East Lothian, Mid Lothian, West Lothian, Renfrewshire, Lanarkshire, Peebleshire, Selkirkshire and parts of Dumfriesshire and Ayrshire, comprising 142 hectads (see Figure 2). The survey area did not include much of Dumfries and Galloway where 51 hectads were surveyed during the 2012 Expansion Zone Survey (Croose *et al.,* 2013).

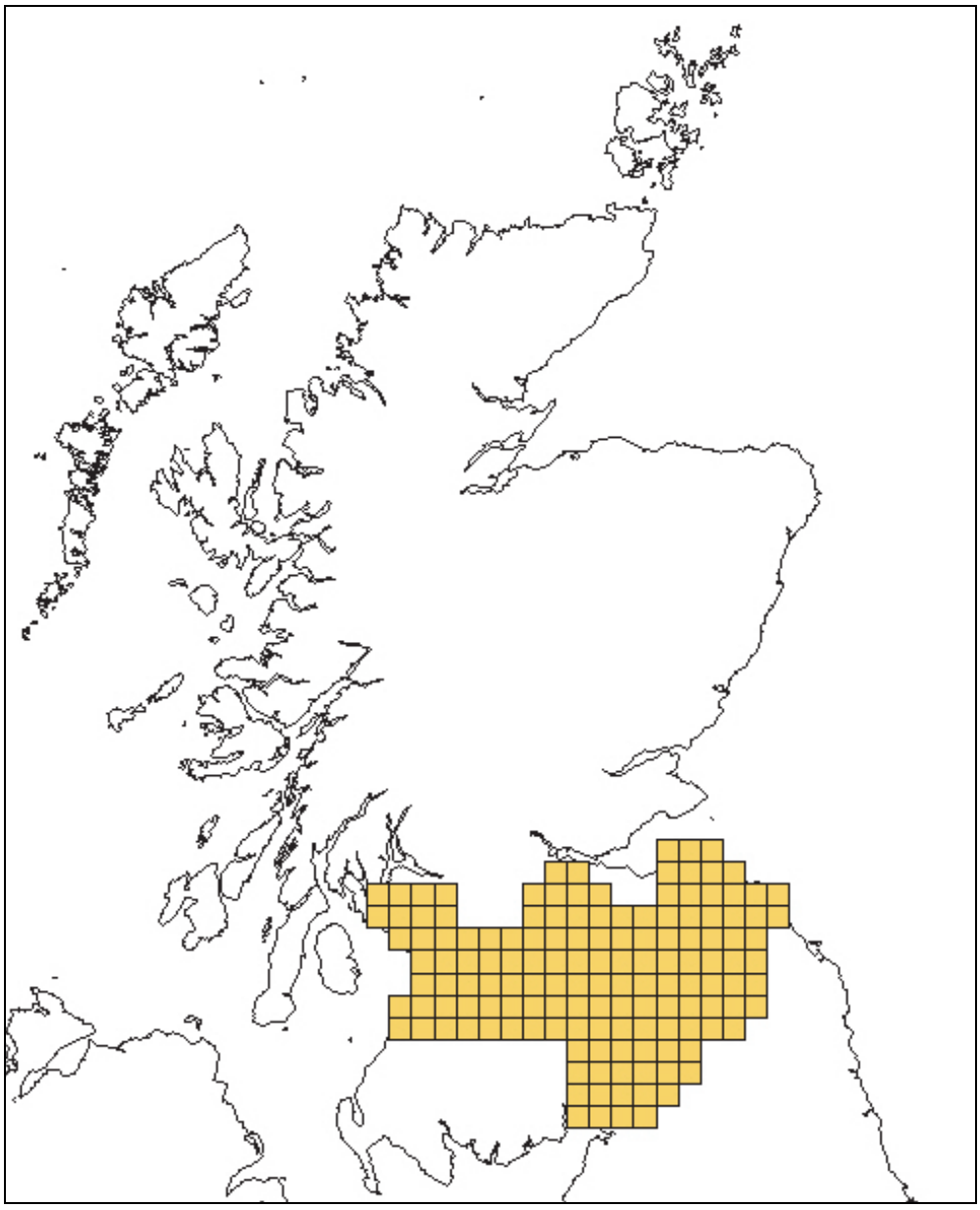

Figure 2. The 2013 target pine marten survey area. Based upon Ordnance Survey material with the permission of the Controller of HMSO © Crown Copyright (2013) Licence no. 100017908.

2.2 Scat survey methodology

2.2.1 Transect approach

The scat survey methodology was adapted from that used during the 2012 Expansion Zone Survey (Croose *et al.,* 2013). This approach was based on recommendations by Macdonald *et al.* (1998) who suggest 'standardised 1km transect searches for field signs along tracks, paths and field boundaries' for monitoring pine martens. The methodology used for the 2012 survey involved surveying one 1km transect in each hectad within the survey area. This sampling approach resulted in a significant probability of 'false negatives' arising because the survey's relatively low sampling frequency was unlikely to detect the presence of pine martens in some hectads, particularly towards the fringes of the species' range and/or where the pine marten population density was low. To increase the chances of detecting pine marten presence in the current survey, where pine marten population density was expected to be much lower than in the species' core range, a higher sampling intensity was adopted whereby three 1km transects were surveyed in each hectad. This was similar to a recent wide-scale pine marten distribution survey of Ireland, in which three transects, each approximately 1.5km in length, were surveyed in each hectad (O'Mahony *et al.,* 2012). Each transect was only surveyed on a single occasion.

2.2.1.1 Targeting of suitable woodland

Transect selection operated at two levels: firstly, targeting of suitable woodland blocks for survey and secondly, selection of transect routes within targeted woodland blocks. Within each hectad the most extensive woodland block with tracks or footpaths present was targeted for locating transects; in hectads with low and/or fragmented woodland cover, transects were located in the largest available block of woodland.

2.2.1.2 Selection of transect routes

Transects were preferentially routed along forest tracks, footpaths or trails in woodland. Transects were normally selected at locations with reasonably easy access for surveyors (i.e. close proximity to a public road) (see Plate 1).

Each transect was separated from other transects in the same or adjacent hectads by a minimum of 3km where practicable, in order to reduce the chances of collecting scats from the same animal and, thereby, to ensure independence of sampling points. However, this was not always possible, particularly in hectads where woodland cover was limited; in this case, transects were located in the same block of woodland or routed together, i.e. two 1km transects followed on from one another to effectively make a 2km transect. In hectads where there was not sufficient habitat in which to survey three transects, two or one transect(s) were surveyed, depending on woodland availability.

Transects were marked onto Ordnance Survey maps using MapInfo Professional 11.5. Each transect was allocated a unique identifier number (UID) matched to a 10 figure National Grid Reference which corresponded to the starting point of the 1km transect.

Plate 1. Examples of transects surveyed for pine marten scats.

2.2.1.3 Transect alteration

For each hectad, where possible, four transects were pre-selected in order to provide an 'extra' transect as an alternative to survey, should any of the other three transects be unsuitable. If a surveyor(s) arrived at a transect to find it unsuitable for the scat survey (e.g. woodland was no longer present or the track was very overgrown) or inaccessible (e.g. due to harvesting operations or private access restrictions), an alternative transect was surveyed. In hectads where woodland cover was limited and no other suitable transects were available, no replacement transect was surveyed.

2.2.2 Hectad exclusion

Hectads with insufficient woodland habitat for the survey methodology to be deployed were excluded from the field survey. Examples of these included hectads in which woodland was scarce or absent, and/or those dominated by urban, suburban, open moorland, agricultural and coastal land types (e.g. saltmarsh, shingle, sand dunes and cliffs).

2.2.3 Scat survey approach

Scat surveys were carried out in 2013 between May and July. This was consistent with the timings of the 2012 Expansion Zone Survey, as previous fieldwork has indicated that pine marten scats are likely to be most abundant on woodland tracks in the summer months (e.g. Velander, 1983; Cresswell *et al*., 2012) and the weather is typically more favourable for fieldwork.

Experienced surveyors walked each transect for 1km, measured using a GPS unit, searching for and collecting possible pine marten scats (see Plate 2). Eight survey teams were used during the survey, comprising 11 surveyors; all were either staff of The Vincent Wildlife Trust, contractors or experienced volunteers (who were professional conservationists or ecologists) with experience of marten scat surveys in Britain and/or Europe. Surveyors worked individually or in pairs surveying an average of six transects per team per day. Two surveyors used scat detection dogs to assist in finding marten scats on transects.

An inclusive approach to scat collection was adopted, whereby surveyors collected any scats that could not confidently be ruled out as coming from other species. This approach was intended to maximise the likelihood of collecting marten scats; an inevitable consequence was that it resulted in collection of some scats from other species.

Plate 2. A pine marten scat in the field, prior to collection.

2.2.3.1 Scat collection

Scats were lifted from the ground using clean wooden 'lolly' sticks (small hard wooden sticks, measuring 11cm long by 4cm wide), which were used once only to avoid contamination of DNA between scats. Each scat was placed into a separate plastic zip-locked sample bag with a unique identification number. This identification number was assigned to the scat and recorded on a survey sheet with a 10 figure grid reference, habitat code and description of the scat. Surveyors rated scats as low, medium or high confidence of being from a pine marten, based on size, morphology and smell. For each transect, surveyors recorded key variables including weather, number of fox scats seen, woodland type and structure and factors affecting detectability of scats such as vehicle and recreational use on the transect (i.e. evidence of vehicles or their tracks, bicycles, horse riders and/or walkers), harvesting activity (evidence of recent timber extraction or clearfell) and level of vegetation on the track (presence and extent of any vegetation).

After collection, all scats were frozen in order to preserve DNA and subsequently posted to Waterford Institute of Technology for DNA analysis.

2.2.3.2 Use of scat detection dogs

The practice of involving trained dogs in wildlife surveys to maximise detection success is well-established (Wasser *et al*., 2004). By harnessing the olfactory searching ability, high play drive and reward-based motivation of certain breeds, dogs can be trained to detect and respond to the scent left by a wide range of elusive species. In this survey, as in the preceding 2012 survey elsewhere in Scotland, two contract surveyors (J. Martin and J. Birks), operating independently as solo surveyors, were each accompanied by a scat detection dog that had been trained to detect the scent of pine marten scats. Training in advance of the survey involved the handlers creating an association within the dogs between the scent of pine marten scats and verbal praise combined with a 'fun' reward (usually a game with a favourite toy). The scats used during training were fresh samples of known origin collected from the lids of pine marten den boxes in Galloway Forest and frozen to preserve their scent.

The dogs searched each survey transect in close proximity (<20m) to the human surveyors, who inspected each scat that their dog showed an interest in. Because of the association with marten scat scent established in training, the dogs' behaviour on encountering such scent on a survey transect was distinctive when compared with their reaction to other scents: typically the dogs lingered longer when smelling marten scats and tended to look at their owners in anticipation of a reward. All scats producing such a response were collected as detailed above. In addition to observing their dogs, the human surveyors searched for scats along the same transects and collected any that appeared to be from pine martens.

2.3 DNA analysis

DNA was extracted from scats as described previously (O'Reilly *et al*., 2008). The presence of pine marten and fox DNA was determined using the pine marten and fox specific quantitative real time polymerase chain reaction (qPCR) assay as described previously in O'Reilly *et al.* (2008) and Mullins *et al*. (2010). The qPCR assay was also used to quantify the DNA to identify samples suitable for DNA sequencing. A 315 bp fragment of the mitochondrial control region was PCR amplified using primers LMS3 (5' TCC CTA AGA CTCAAG GAA GA 3') (Statham, 2005) and PM-Rev (5' GGC CCG GAG CGA GAA G 3') (O'Reilly *et al*. 2008). The 10 µL PCR reaction contained 5 µL GoTaq® Hot Start Green Master mix (Promega Corporation, 2800 Woods Hollow Road, Madison, WI 53711, USA, Cat. No. M5123), 200 nM each primer and 2-10 ng DNA. The thermal cycling protocol was 94°C initial denaturation for 2 minutes, followed by 50 cycles of 94°C for 20 seconds, 57°C for 30 seconds and 72°C for 30 seconds with a final extension for 10 minutes at 72°C. PCR

products were purified for sequencing using a DNA Clean and Concentrate-5™ (Zymo Research Corporation Cat. No. D4004). The PCR products were sequenced on both strands using the Applied Biosystems BigDye® v3.1 cycle sequencing kit (Life Technologies Corporation, 5791 Van Allen Way, PO Box 6482, Carlsbad, California 92008, USA) used according to the manufacturer's instructions. The sequencing reaction was analysed using 13 the ABI 310 Genetic Analyser. DNA sequences were analysed using the Lasergene software package (DNASTAR Inc.3801 Regent Street, Madison, WI 53705 USA).

2.4 Collection of recent records in addition to the field survey

2.4.1 Collection of recent records from within the survey area

In addition to the field survey, records of pine martens from post-1999 were gathered from a variety of organisations and individuals. Only verified records were accepted; sightings were deemed to be verified if they had been validated by county mammal recorders or Local Biological Record Centres; were from experienced, reliable observers; or were supported by a carcass or photograph. These records predominantly came from the Dumfries and Galloway county mammal recorder (Riches, 2010, 2012), Forestry Commission Scotland, Scottish Society for the Prevention of Cruelty to Animals (SSPCA) and a naturalist living within the survey area. In addition, in keeping with the approach used in the 2012 Expansion Zone Survey (Croose *et al*., 2013), unverified sightings were classed as 'probable positive' records.

2.4.2 Collection of recent records from outside of the survey area

Recent verified records of pine martens were additionally collected from the 2012 Expansion Zone Survey area, from hectads that were recorded as negative or 'probable positive' for pine marten during that survey. These were predominantly gathered from existing contact with wildlife conservation organisations, researchers and naturalists and *ad hoc* records sent to The Vincent Wildlife Trust. These records (see Plate 3) were used to update the overall pine marten distribution map produced in Croose *et al.* (2013) and to fill in gaps where presence of pine martens had not recently been recorded.

Plate 3. Example of a record used to update the 2012 Expansion Zone survey, showing a pine marten being released after accidental capture in a squirrel trap in Aberdeenshire in December 2012 (© Steve Willis, Saving Scotland's Red Squirrels)

3. RESULTS

3.1 Field survey

3.1.1 Transects surveyed

Two hundred and ninety eight transects in 117 hectads were surveyed for scats during the survey period of May to July 2013. The sampling density of three transects per hectad was successfully deployed in 67% of hectads (n=78); two transects were surveyed in 20% of hectads (n=23) and one transect was surveyed in 13% of hectads (n=16). This lower sampling density in some hectads is a reflection of the scarcity of woodland habitat suitable for the field survey in parts of the survey area.

3.1.2 Scat collection and DNA analysis

One hundred and eighty four scats were collected during the field survey and subjected to DNA analysis. Of these, 39% (n=72) were determined to species level in the laboratory: 4% (n=8) were identified as pine marten and 34% (n=63) were identified as fox. One scat (1%) was identified as stoat *Mustela erminea* following repeat sequencing. The remaining 61% of scats (n=113) did not yield sufficient DNA for the species of origin to be determined in the laboratory; these are classed as 'not determined' scats (see Table 1). Ten scats that did not yield DNA had been classed by surveyors with a 'high' degree of confidence as being pine marten; therefore, these are classed as 'probable positive' records, based on surveyor judgement.

Table 1. Species origin of scats collected as determined by DNA analysis.

Species (determined by DNA analysis)	**Number of scats**	**Percentage of scats**
Pine marten	8	4%
Fox	63	34%
Stoat	1	1%
Not determined	113	61%
Total	**184**	

3.1.3 Haplotype of scats collected

All pine marten scats determined in the laboratory were sequenced to determine haplotype. 63% of scats (n=5) had sufficient DNA to determine haplotype; these were all haplotype *a*. Haplotype *a* is currently the dominant haplotype for pine marten in Scotland (Jordan *et al*. 2012) and all pine marten scats sequenced during the 2012 Expansion Zone Survey were haplotype *a* (Croose *et al.* 2013).

3.1.4 Efficacy of scat detection dogs

Two surveyors with scat detection dogs surveyed a relatively small proportion of the survey area, accounting for 25% of the transects surveyed (n=75).

The effectiveness of scat detection dogs was demonstrated by one surveyor's (J. Birks) experience on a transect in Whitelee Forest, East Renfrewshire in 'Area A' (see section 3.3 for classification of areas). The transect was on a little-used forest track that, nevertheless, had experienced some recent limited vehicle use. Part-way along the transect the dog reacted strongly to scent present within a set of fresh tyre tracks; close inspection revealed two 'smears' of fresh faecal matter approximately 1 metre apart, both of which had been crushed into the surface of the track, which comprised moist, gritty mud of a similar colour to the faecal matter. Both samples were collected and subsequent DNA analysis confirmed that they were pine marten scats; furthermore the DNA was of sufficient quality to reveal that the

two scats had been produced by different animals, one male and one female. No other potential marten scats were found on the transect by either the dog or the human surveyor; the other two transects in the same hectad were negative and no other hectads in this part of the survey area were DNA-positive. Because both scats had been crushed by a vehicle into the surface of the track, which was of a similar colour to the scats, it is highly unlikely that either would have been detected and collected as a potential marten scat by the human surveyor working on his own. Thus the involvement of a dog in this instance transformed a 'human negative' transect into the only DNA-positive transect in the hectad. This, in turn, was the only DNA-positive hectad in that part of Scotland, hence providing evidence of the presence of pine martens in an area where the species had not previously been recorded.

Neither of the dogs indicated interest in any scats other than those found in Whitelee Forest and none of the other scats collected by the two human surveyors with dogs were identified as pine marten through DNA analysis.

3.2 The occurrence of positive hectads

The eight confirmed pine marten scats, verified via DNA analysis, were found in five hectads (4% of hectads surveyed); these were classed as 'DNA positive' hectads. Two of these hectads also had records collected in addition to the field survey. 'Probable positive' records comprised a further four hectads (3% of hectads surveyed); these were hectads in which scats were collected that had been classed by surveyors with a 'high' degree of confidence as being pine marten but did not yield DNA in the laboratory (two hectads), or in which unverified sightings were reported (two hectads).

Verified pine marten records collected post-1999, in addition to the field survey, (see section 2.4) were collected from 13 hectads (11% of hectads) within the survey area. As aforementioned, two of these hectads were corroborated by 'DNA positive' scats collected during the field survey.

The remaining 97 hectads (83% of hectads surveyed) did not produce any possible pine marten scats, or surveyors collected scats that did not yield DNA in the laboratory, and they were not confident that the scats were from pine martens (see Figure 3).

Hectads positive for pine marten, as a result of the field survey and records collected outside of the field survey, are illustrated in Figure 3.

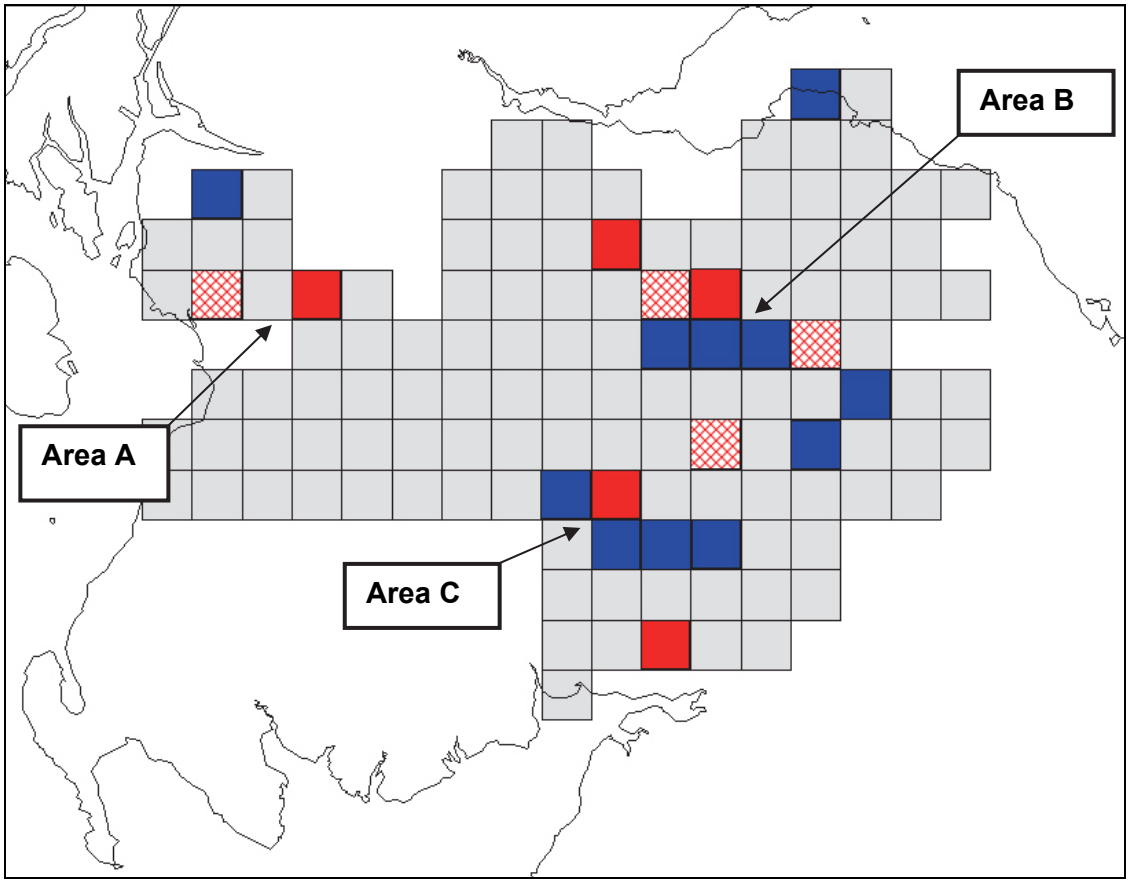

Figure 3. 2013 survey results summary by hectad: DNA positive from field survey (red solid shading); pine marten records collected outside of the field survey (blue shading); probable positive records (red hatched shading); and surveyed hectads in which no evidence of pine martens was recorded (grey solid shading). Note that records of pine martens documented outside of the survey area (e.g. in the Galloway Forest and Central Belt) are not shown here. Based upon Ordnance Survey material with the permission of the Controller of HMSO © Crown Copyright (2013) Licence no. 100017908.

3.3 Pine marten distribution in the southern Scotland survey area

Within the survey area, pine marten presence was confirmed at a number of widely-spaced sites, and appears to be centred on three areas (see Figure 3). For the purpose of analysis, these areas are classified as Areas A, B and C.

Area A: Immediately south and west of Glasgow

Pine marten presence was recorded immediately south and west of Glasgow; this is classed as 'Area A.' Presence in this area was confirmed principally through detection of two pine marten scats, verified via DNA analysis, found close together on the same transect in Whitelee Forest mainly in East Renfrewshire. The high quality of DNA in the scats allowed gender to be determined, and revealed one to be from a male pine marten and the other from a female. Prior to this survey, there had been recent unconfirmed sightings of pine martens in Whitelee Forest (R. Mason, M. Morrison, Y. Grieve, pers. comm.). Pine marten presence is further confirmed by a pine marten carcass found in Clyde Muirshiel Country Park in 2002 (Croose *et al.,* 2013), 30km north-west of the scats found in Whitelee Forest. In 2013, a naturalist reported a sighting of a probable pine marten near Dalry, North Ayrshire, approximately 22km to the west of the scats found in Whitelee Forest; this accounts for the 'probable' positive hectad in that area.

Area B: Upper Tweed Valley

There is a concentration of pine marten records centred on the Upper Tweed Valley in the vice county of Peebleshire, within the vicinities of Peebles, Innerleithen and Galashiels; this is classed as 'Area B.' Here, pine marten presence was confirmed by both DNA-verified scats, found in two hectads, and sightings from third parties, principally Forestry Commission Scotland staff, in three hectads. Two 'probable positive' hectads, in which 'not determined' scats were found, occur adjacent to confirmed positive hectads here.

Area C: Eastern Dumfries and Galloway

There is a concentration of pine marten records in eastern Dumfries and Galloway centred on Annandale and Eskdalemuir Forest; this is classed as 'Area C.' The majority of the positive hectads here were based on records from the recent County Mammal Reports for the vice counties of Dumfriesshire, Kirkcudbrightshire and Wigtownshire (Riches, 2010; 2012); these occur in four hectads. Two hectads were 'DNA positive' via pine marten scats found during the field survey; one of these hectads is located 2km east of Moffat, while the other is further south near Annan, only 14km from the English border.

The proportions of hectads positive and negative for pine martens by vice county is summarised in Table 2. In this report, in keeping with the 2012 Expansion Zone Survey (Croose *et* al., 2013) and other recording exercises, we have used the system of Watsonian vice-counties; see map of vice county boundaries.

Table 2. Number of positive and negative hectads for pine marten by vice county surveyed.

*Vice county	**Hectads included in survey area	Hectads positive for pine marten	Hectads probable positive for pine marten	***Total number hectads positive for pine marten	***% positive hectads (rounded to nearest whole number)	Hectads negative for pine marten
Ayrshire	35	1	1	2	6	33
Berwickshire	14	0	0	0	0	14
Dumfriesshire	26	6	0	6	23	20
East Lothian	10	1	0	1	10	9
Kirkcudbrightshire	26	0	0	0	0	26
Lanarkshire	22	0	0	0	0	22
Mid Lothian	8	1	0	1	13	7
Peebleshire	13	4	1	5	38	8
Renfrewshire	7	1	0	1	14	6
Roxburghshire	19	1	1	2	11	17
Selkirkshire	6	1	1	2	33	4
West Lothian	4	0	0	0	0	4
Totals	190	16	4	20	11	170

**See hyperlink in above paragraph for a map showing vice county boundaries. **Not all of these hectads were surveyed as some were excluded from the field survey (see section 2.2.2). ***Includes positive and probable positive hectads.*

3.4 Overall pine marten distribution in Scotland 1980-2013

During the course of the 2013 survey in southern Scotland, pine marten records were collected from 24 hectads further north, that had previously been recorded as negative or 'probable positive' for pine martens during within the 2012 Expansion Zone Survey area. These records filled in gaps where presence of pine martens had previously been unrecorded and allowed the map for overall pine marten distribution in Scotland produced in Croose *et al.* (2013) to be updated.

The distribution of pine martens in Scotland as depicted by the current survey, the 2012 Expansion Zone Survey (Croose *et al.,* 2013), the 1994 distribution survey (Balharry *et al.,* 1996) and the 1980-1982 distribution survey (Velander, 1983) is illustrated in Figure 4.

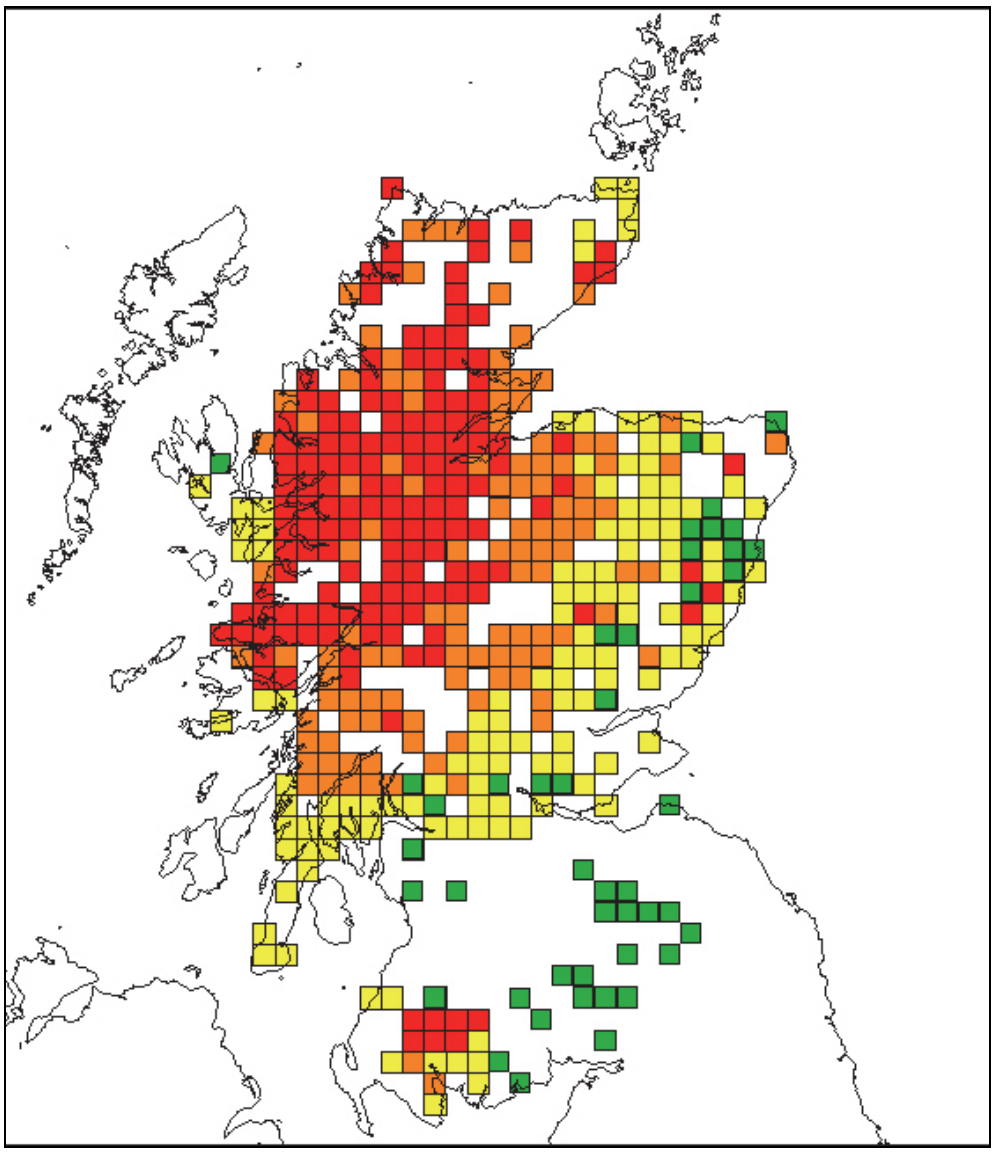

Figure 4. Overall distribution of pine martens in Scotland, comprising records collected from 1980 to 2013. This map includes records collected during the 1980-1982 distribution survey (Velander 1983) (hectads shaded red), the 1994 distribution survey (Balharry et al. 1996) (hectads shaded orange); the 2012 Expansion Zone Survey (Croose et al. 2013) (hectads shaded yellow); and records (both DNA positive and probable positive records from the field survey and non-field survey records) collected during the current survey, including within the 2012 survey area (hectads shaded green). Based upon Ordnance Survey material with the permission of the Controller of HMSO © Crown Copyright (2013) Licence no. 100017908.

4. DISCUSSION

4.1 Distribution, status and origins of pine martens in southern Scotland

Pine marten records are concentrated in three distinct areas in southern Scotland (excluding the well-recorded Galloway population in the south-west, not described here) and it is likely that pine martens may have differing origins and status in each. For the purpose of analysis, these areas are classed as Areas A, B and C (see section 3.3).

Area A: Immediately south and west of Glasgow

The records of pine martens immediately to the south of the Central Belt may have originated via expansion of the core population further north in the Highlands, and could be indicative of pine martens spreading south through the Central Belt. Pine martens were confirmed in Cumbernauld in North Lanarkshire, north-east of Glasgow, during the 2012 Expansion Zone Survey, followed subsequently by images of a pine marten captured on a camera trap in the same area in 2013 (D. Clark, pers. comm.), and pine martens recorded nearby near Twechar in 2013 (C. Smith, pers. comm.). In 2013, a pine marten road kill was found in Bishopton, west of Glasgow, indicating that martens may be using the Erskine Bridge to move across the River Clyde (R. Raynor, pers. comm.). The 'DNA positive' hectad in Whitelee Forest is approximately 30km from the aforementioned positive hectads, which are within the Central Belt. Only one hectad was 'DNA positive' from the field survey and only one hectad was a 'probable positive' as the result of a sighting of a marten (22km west of the DNA positive hectad). No evidence of pine martens was confirmed in the surrounding area so it is likely that their occurrence to the south of the Central Belt is a relatively recent phenomenon and their spread through the Central Belt has been limited. However, the possibility cannot be ruled out that martens have been translocated to Area A from elsewhere in Scotland. Whatever their origins, it seems likely that pine martens in this area are at an early stage of population establishment; the confirmation, via DNA analysis of scats, that both a male and female marten was present in Whitelee Forest in 2013 indicates the potential for reproduction.

Area B: Upper Tweed Valley

The pine marten population centred on the Upper Tweed Valley in Peebleshire has reportedly originated from multiple releases of pine martens, rescued and rehabilitated by the SSPCA. These unofficial translocations have not been undertaken in consultation with SNH. A total of 14 pine martens have been released into forestry near Innerleithen over the period 2007 to 2013 (C. Seddon, pers. comm.). A series of sightings dating from 2010 suggests that a population is becoming established in this area.

Area C: Eastern Dumfriesshire

The origin of the pine martens recorded in Annandale and Eskdalemuir is uncertain. The most westerly record (a sighting reported in the Lowther Hills in Riches (2012)) is some 40km from the recorded easterly limit of the pine marten population in Galloway Forest documented in the 2012 Expansion Zone Survey. Range expansion of the population in this area was deemed to be limited (Croose *et al.,* 2013). However, two sightings records, submitted to Dumfries and Galloway Environmental Records Centre, have been reported in the Nith Valley, which lies between the core Galloway population and Annandale. The DNA positive scat found east of Moffat is within 35km of Area B where martens have been released by the SSPCA. Records in eastern Dumfriesshire are also within reasonable proximity (within 30km) of records of pine martens in the north of England during the 1990s (Birks & Messenger 2010). Nevertheless, due to the somewhat isolated nature of this concentration of records human intervention, in the form of the translocation and release of pine martens, cannot be ruled out. On this evidence, it is difficult to be certain about the status of pine martens in this area.

Occasional records

A pine marten carcass was collected on the north coast of East Lothian in 2004. The origin of this animal is uncertain as there is no other evidence of pine marten presence in this area.

4.2 Prospects for future range expansion

The evidence of current presence of pine martens in several areas in southern Scotland could provide a mechanism for re-colonisation of the south of Scotland, as well as the north of England, habitat, biological and anthropogenic constraints permitting.

Woodland cover in southern Scotland varies from 26.8% in Dumfries and Galloway (the region with the highest woodland cover in Scotland), 18.5% in the Borders and 10.4% in Lothian (the region with the lowest woodland cover in mainland Scotland) (Forestry Commission, 2001). However, regardless of the extent of woodland cover, it is important to assess the capacity of this habitat in southern Scotland to provide the ecological conditions required by a self-sustaining pine marten population. The woodland cover in much of southern Scotland is dominated by relatively young plantations at the closed-canopy stage or clear-fell (see Plate 4), which provide poor quality habitat for pine martens (Caryl *et al.,* 2012). In a radio-tracking study of pine martens in north-east Scotland, closed-canopy forest was used less by martens than was available at a home range level, possibly due to a lack of cover near the ground (Caryl *et al.,* 2012). In particular, young closed-canopy forests lack elevated insulated den sites which provide suitable sites in which martens can shelter and breed successfully. Therefore, in these sub-optimal woodland habitats, pine martens may survive at low densities but breeding may be constrained by habitat limitations. During another radio-tracking study at a site in north-west Scotland, pine martens showed a significant preference for closed-canopy commercial forestry (Balharry, 1993). However, that part of the marten's range is dominated by rocky, mountainous landscapes that provide alternative three-dimensional habitat features when arboreal den sites are limited within closed-canopy forestry. The landscape of much of southern Scotland lacks three-dimensional features to provide alternative denning sites for pine martens when woodland structure is unsuitable.

Plate 4. Young conifer plantations and blocks of clearfell in the Scottish borders.

There is a relatively high prevalence of shooting estates managed for red grouse in southern Scotland and land-use composition on these grouse moors is dominated by montane, heath, bog and semi-natural grassland habitats (Game & Wildlife Conservation Trust, 2013). These are unlikely to provide suitable habitat for pine martens. They avoid open areas, particularly agricultural fields (Pereboom *et al.,* 2008), moorland (Balharry, 1993; Caryl *et al.,* 2012) and pasture (Balharry, 1993) and their reluctance to cross large areas without cover means that martens may not use even relatively nearby forest fragments if they are isolated by unsuitable intervening habitats (Caryl *et al.,* 2012). This may limit their ability to disperse and colonise areas of fragmented forest cover (Caryl, 2008) and may restrict future range expansion in southern Scotland, given the prevalence of heath and other inhospitable open habitats. Furthermore, predator control on and around grouse moors may increase the vulnerability of pine martens to accidental mortality resulting from non-target effects of predator management.

Nevertheless, where populations are well-established, pine martens do occur in certain non-woodland habitats in parts of Scotland, such as montane habitats in the Cairngorms, blanket bog in the Flow Country and coastal habitats in Wester Ross (Croose *et al.,* 2013), as well as in agricultural landscapes in Italy (Balestrieri *et al*., 2010) and fragmented forest habitats in France (Mergey *et al*., 2011). Unsuitable habitats may be more likely to be crossed and/or occupied by dispersing individuals rather than used by resident individuals within their home range.

Predictions for future range expansion and re-colonisation in southern Scotland must be tempered by the uncertainties surrounding the origin and status of the populations in this area. At least two populations in southern Scotland have originated from a release of a small number of animals: the population in the Galloway Forest and the population in the Upper Tweed Valley. Small populations are more vulnerable to stochastic processes (demographic stochasticity, environmental stochasticity and genetic stochasticity) that can adversely affect population growth and stability (Lacy, 2010). It has been suggested that the limited expansion of the pine marten population in Galloway Forest may be due to genetic constraints arising from founder effects from the very small number of individuals that were reintroduced (Croose *et al*., 2013). Therefore, if one assumes that the number of pine martens originally released in southern Scotland is relatively low, range expansion of the current populations may be limited. However, dispersal of pine martens from the core population north of the Central Belt could increase gene flow and genetic diversity within populations in southern Scotland and thereby facilitate more active range expansion.

If the constraints discussed can be overcome, pine marten populations in the south of Scotland are likely to become contiguous over time: the populations in the Tweed Valley and Annandale could join up with the Galloway Forest population and ultimately become contiguous with the core population spreading south through the Central Belt.

Future range expansion of pine martens from southern Scotland into the north of England will depend on suitability and connectivity of habitat. Northumberland has 17.4% woodland cover (Woodland Trust, 2013a), including the heavily forested Kielder Forest and Wark Forest which, depending on woodland type and structure, could provide suitable habitat for martens re-colonising this area. Woodland cover in Cumbria is much lower at 10% (Woodland Trust, 2013b). Evidence indicates that a small population of pine martens survives in Northumberland and Cumbria, with records from the 1990s occurring within 10km of the Scottish border (Birks & Messenger, 2010), and a pine marten scat found in the Cheviot Hills in 2010, just 7km from the Scottish border (VWT, unpublished data). If the pine marten population in southern Scotland is able to expand its range into the north of England, habitat and anthropogenic constraints (i.e. illegal persecution) permitting, an increase in gene flow would benefit the extant marten population(s) in Northumberland and Cumbria.

4.3 Survey methodology

4.3.1 Transect density

The results from the field survey demonstrate that increasing the density of transects from one 1km transect per hectad as used in the 2012 Expansion Zone Survey (Croose *et al.,* 2013) to three 1km transects per hectad, similar to the methodology of the pine marten distribution survey of Ireland (O'Mahony *et al.,* 2012), increased the chance of encountering pine marten scats. In four of the five hectads in which pine marten scats were collected and verified by DNA analysis, 'DNA positive' scats were only found on one of the three transects surveyed, and in the fifth hectad, 'DNA positive' scats were found on one of two transects surveyed. Therefore, the scat detection rate for these hectads was 33% on average, with two-thirds of transects failing to yield DNA positive pine marten scats despite pine martens being present in the hectad. If only one transect had been surveyed per hectad, this would have resulted in an increase in the proportion of false negative hectads. These results justify increasing the density of transects surveyed, which may be particularly important in areas where pine martens occur at low densities and the availability of scats is lower.

Recent occupancy modelling by McHenry (2013) demonstrated that transects of 1km were successful at detecting pine martens, where present, with average probabilities of 0.33, which closely matches the findings of this survey, as stated above. Hence, it is recommended that future distribution surveys follow the methodology of the current survey, based on three 1km transects per hectad, in order to maximise probability of detection.

4.3.2 Methodological constraints

4.3.2.1 DNA verification of scats

The proportion of scats that was not determined to species level by DNA analysis (61%) was high, despite repeated attempts at analysing scats that surveyors had classed with a high degree of confidence as being from pine marten. This compares poorly with the 2012 Expansion Zone Survey in which 48% of scats were non-determined (Croose *et al.,* 2013); a 2011 pine marten survey in Argyll in which 1% of 157 scats were non-determined (VWT, unpublished data); and a predator survey by The Game and Wildlife Conservation Trust in which 25% of 414 scats were non-determined (Baines *et al*., 2011).

One explanation for the high proportion of non-determined scats is that the DNA contained in the scats may have been lost or degraded by exposure to the elements. Success rates of PCR amplification of carnivore scats decline significantly as a consequence of exposure to wet weather (Farrell *et al.,* 2000). It was postulated that this may have been a critical factor that resulted in the high rate of non-determined scats in the 2012 Expansion Zone Survey, when heavy rain was experienced during much of the field work (Croose *et al.,* 2013). However, much of the current field survey was undertaken during dry and warm conditions associated with the 'heat wave' of July 2013. Exposure to ultraviolet light may have an adverse effect on DNA degradation and sample quality (Murphy *et al.,* 2007), thus the sunny conditions during the survey may have increased the degradation rate of DNA in scats. Furthermore, the prolonged period of dry weather in June and July will have resulted in many scats being in situ on transects for days or even weeks, and time in the field is a critical variable in DNA amplification success rates (Murphy *et al.,* 2007). Success rates for nDNA PCR amplification of brown bear *Ursus arctos* faecal samples have been found to be low after only three days in the field (Murphy *et al.,* 2007) and samples of Asian elephant *Elephas maximus* dung have failed to provide amplification products when collected a few days after deposition (Fernando *et al*., 2000).

Another explanation that may account for non-determined scats is that they may have originated from a species other than pine marten or fox and therefore would not have been identified through sequencing. Collection of scats from other mustelids, such as stoat, mink

Neovison vison, polecat *Mustela putorius* or ferret *Mustela furo*, cannot be ruled out. Even some bird droppings, such as weathered pheasant *Phasianus colchicus* droppings and corvid *Corvidae* pellets, may look similar to carnivore scats. Surveyors adopted an inclusive approach to scat collection, whereby all scats that could not confidently be ruled out as coming from another species were collected. This approach was intended to maximise the likelihood of encountering marten scats; an inevitable consequence was that, compared with sites where marten scats are frequently encountered, it was more likely to result in collection of a higher proportion of scats from other species.

The prevalence of non-determined scats is likely to have resulted in the occurrence of false negatives in the current survey, where scats from pine martens were collected but failed to produce pine marten DNA during laboratory analysis. Scats classed by surveyors as 'high confidence' of being from pine marten, on the basis of morphology, yet did not yield DNA in the laboratory were found in three hectads.

The low number of pine marten scats found (4% of scats collected; n=8) compares poorly to the 2012 Expansion Zone Survey, in which 38% of scats collected (n=97) were confirmed as pine marten by DNA analysis. This is likely due to the very low number and population density of pine martens in the survey area, compared with the core population surveyed during the 2012 survey. Furthermore, surveyors adopted an inclusive approach to scat collection, whereby all scats that could not confidently be ruled out as coming from another species were collected. This approach was intended to maximise the likelihood of encountering marten scats; an inevitable consequence was that, compared with sites where marten scats are frequently encountered, it was more likely to result in collection of a higher proportion of scats from other species.

4.3.2.2 The availability of detectable scats

It is highly unlikely that all individuals present will be detected during a study (MacKenzie *et al*., 2011). Imperfect detectability, where a species is present at a site but goes undetected, is common in monitoring programmes and can lead to underestimates of true distribution and occupancy (Karanth *et al*., 2011). There are myriad variables that affect the availability and detectability of pine marten scats on transects, as summarised by Croose *et al*. (2013). Notably, the 'standing crop' of available scats is influenced by recent patterns of rainfall; patterns of vehicle use on transects; and recreational use (e.g. walkers, cyclists, horse riders) of transects. Detectability of scats is influenced by the extent and nature of vegetation growing on a transect; the texture and colour of the transect surface; consumption of scats by slugs (Birks *et al.,* 2004); and the content of marten scats, which may differentially influence their longevity. McHenry (2013) found that detection probabilities of pine marten scat surveys were most negatively influenced by vegetation cover, while increasing transect width had a positive influence on detection probabilities. Differences in the experience and visual acuity of surveyors and the use of scat detection dogs may also influence the number of marten scats detected on transects.

4.4 Recommendations for future work

4.4.1 Recording pine martens and monitoring changes in southern Scotland

The range expansion and changing distribution of the pine marten in Scotland warrants continued monitoring, particularly as the species re-colonises areas with higher human populations and the associated potential for conflicts with humans increases (for example, martens denning in inhabited buildings). The confirmation of pine marten presence at several sites in the south of Scotland is particularly worthy of further investigation and those planning future monitoring programmes should consider incorporating sites in the north of England in close proximity to the Scottish border, in order to detect range expansion into England. Recording pine martens on an *ad hoc* basis (i.e. recording road casualties, live

sightings, animals on camera traps and potential use of raptor and owl nest boxes) should be encouraged in order to monitor changing patterns of distribution between systematic distribution surveys. Future distribution surveys should also encompass areas further north in which the re-colonisation of pine martens has been incomplete, as recorded in the 2012 Expansion Zone Survey (Croose *et al.,* 2013); notably eastern Aberdeenshire, Angus, Fife, Stirlingshire and the Central Belt.

4.4.2 Improving habitat quality and connectivity between pine marten populations

Given the probable low numbers of pine martens and the relative isolation of populations in southern Scotland, encouraging connectivity between woodlands could facilitate range expansion of and gene flow between populations. Den boxes are used readily by breeding female martens to raise their kits in Galloway Forest (J. Birks, personal data) and could be deployed in other areas to provide natal den sites and encourage breeding. The establishment of woodland corridors and hedgerows could provide important ecological connectors between larger woodlands (Pereboom *et al.,* 2008) to facilitate dispersal and range expansion. A strategic approach to habitat improvement for pine martens would be desirable.

4.4.3 Assessing the genetic status of pine martens in southern Scotland

The genetic status of pine martens in southern Scotland should be investigated in order to identify any founder effects, arising from the small number of individuals released in Galloway Forest and the Upper Tweed Valley which may constrain future range expansion of the populations. Non-invasive sampling of hairs from ‘hair tubes’ (sections of baited plastic drainpipes erected on trees) and scats can provide genetic data which could be analysed to assess genetic variability within populations. This method has been used successfully to study pine marten genetics in Ireland (Mullins *et al.,* 2010) and north-east Scotland (Kubasiewicz, in prep.).

5. CONCLUSION

Based upon genetic verification of faeces in each case, this survey has confirmed the presence of pine martens in three separate areas of southern Scotland. The three locations are widely spaced and all lie beyond the population established in Galloway Forest following a translocation in the early 1980s. Evidence suggests that pine martens arrived at these new locations much more recently than the 1980s but, with the exception of the Upper Tweed Valley 'population' that was reportedly established by a series of unofficial releases from 2007 onwards, their origins are uncertain. The eastern Dumfries and Galloway 'population' could possibly have arisen via dispersal eastward of individuals from the Galloway Forest population and the 'population' to the south and west of Glasgow may have originated from natural dispersal of pine martens southward through the Central Belt, but human intervention cannot be ruled out in both cases.

The extent to which breeding populations of pine martens are established in these new locations remains unknown and should be confirmed by future monitoring. Given the limited geographical extent of verifiable evidence in each case, it is likely that pine martens are at a very early stage of population establishment in all three areas. Nevertheless, if breeding populations establish successfully, this provides a mechanism for eventual range expansion in suitable habitat throughout southern Scotland and southward into northern England. However, considering the very limited range expansion shown by the Galloway Forest population since its establishment over 30 years ago, expectations of future spread from the new areas should be moderated accordingly.

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