Chapter 12

ARE SCAT SURVEYS A RELIABLE METHOD FOR ASSESSING DISTRIBUTION AND POPULATION STATUS OF PINE MARTENS?

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Abstract: Systematic searches for marten feces or 'scats' have been used since 1980 for assessing the status of protected populations of pine martens (*Martes martes*) in Britain. Previous surveys using scats have relied on unsubstantiated assumptions that martens typically defecate along roads and trails, that martens inhabit primarily woodland habitats, and that scats from martens can reliably be distinguished from those of other carnivores. Results of scat surveys have drawn conflicting conclusions about population status, which has lead to disagreement about conservation action, and doubts about the reliability and validity of assumptions associated with the technique. We reviewed the recent history of survey programs for pine marten populations in Great Britain. We examined the assumptions made in different surveys and considered these critically. The scat survey technique has several limitations, and is likely to be least reliable where populations of martens are low and where distribution is uneven. New DNA testing approaches revealed the inaccuracy of marten scat identification in the field. We recommend that scat surveys should be conducted only when genetic verification is available to confirm scat identity.

1. INTRODUCTION

Surveying wildlife populations is an important tool for management and conservation because distribution and abundance data derived from systematic surveys are needed to make policy decisions. In the UK, monitoring of wildlife populations is essential if the Government is to meet its obligations to maintain or restore the favorable conservation status of key species, under the European Commission's Habitats and Species Directive (e.g., Macdonald et al. 1998, Toms et al. 1999).

Carnivores present particular problems for those devising programs to survey or monitor populations (Gese 2001). For martens, data may be derived from trapping returns (e.g., Strickland 1994, Aune and Schladweiler 1997, Helldin 1998); however, martens are strictly protected in some states, so alternative approaches to detection and monitoring are necessary. Although marten sightings and carcasses obtained from road-kills may provide useful information on distribution and abundance, they are of limited value for monitoring because sampling effort cannot be controlled. Snow-tracking can be used as a source of winter data on marten in some countries (e.g., Lindström et al. 1995), but snowfall in most of Britain is limited and unpredictable. Track plates and camera traps have been used successfully on martens in some states (Zielinski and Kucera 1995), though not in Britain. Genetic analysis of hairs recovered from bait stations or at dens has been used to confirm the identity of other species (e.g., Woods et al. 1999, Sloane et al. 2000), and has potential for use on marten via hair snagging tubes (Messenger and Birks 2000).

Pine martens are the only *Martes* native to Britain. Outside its Scottish stronghold the species is scarce or absent as a consequence of habitat loss and persecution in previous centuries (Langley and Yalden 1977, Tapper 1992). During the decline of pine martens in the 19th and early 20th centuries, information on distribution and abundance was derived primarily from reports of animals observed or killed by hunters and gamekeepers (e.g., Langley and Yalden 1977, Strachan et al. 1996, Webster 2001). However, the species has been partially protected by law in Britain since 1982, and fully protected since 1988. Instances of deliberate or accidental killing are rarely reported, especially where the species is scarce (e.g., Jefferies and Critchley 1994, Birks et al. 1997, Messenger et al. 1997). Since 1980, assessments of marten status in Britain have been based on systematic searches for scats. Conclusions drawn from such surveys have been used to inform national conservation policies and recovery programs (e.g., Bright and Harris 1994, Bright et al. 1995*a,b*, Bright and Smithson 1997). However, there is concern about the reliability of scat surveys, especially where populations are sparse (Messenger and Birks 2000).

Ecologists derive information on diet, populations, habitat use, and genetics from feces (review by Putman 1984, Boyce 1988, Kohn and Wayne 1997). Many mammals use feces in olfactory communication by depositing them in prominent places throughout their ranges, or at territory boundaries (Gorman and Trowbridge 1989). This 'signing' behavior has enabled ecologists to survey elusive species whose feces and other field signs are easier to find and count than the animals that produce them. For example, Europe's vulnerable populations of otters (*Lutra lutra*) have been monitored since the 1970s by systematic searches for 'spraints' (Mason and Macdonald 1987); however, there has been debate about whether reliable information on distribution and habitat use can be derived from these data (Kruuk et al. 1986, Jefferies 1986, Mason and Macdonald 1987). Despite concerns about correct field identification of scats, and the uncertain relationship between scat abundance and animal population density, surveys have been applied to many carnivores to detect presence or absence and to document distribution (review by Gese 2001).

Recent surveys for pine martens (Table 12.1) have used a method adapted from otter surveys (Lenton et al. 1980). Searches for scats are conducted along linear features, such as forest trails and paths. This technique arose from the work of Lockie (1964), who first suggested a relationship between the numbers of scats and martens. This presumed but untested relationship has encouraged the development of an inexpensive approach to monitoring. A single field surveyor, searching a large number of pre-selected sites, can gather repeated sample data on marten presence over a wide geographical area. However, survey design and interpretation may involve assumptions about habitats utilized by martens, about territorial marking behavior, spatial and temporal patterns of scat-deposition, and field surveyors' identification skills.

We reviewed the application of scat searches as a survey tool, and we evaluated the implications of new DNA techniques used to assess the reliability of scat identification in the field. We assessed the use of scat surveys for inventory and monitoring by addressing three primary questions: (1) Are survey methods and objectives appropriate?, (2) Are scats correctly identified?, and (3) How does the pattern of scat abundance influence results?

2. REVIEW OF SURVEY OBJECTIVES AND METHODS

We evaluated the objectives for 8 previous scat surveys of martens in Britain and 1 in Spain (Table 12.1). We also reviewed the approaches to survey design, considering the selection of geographical areas and habitats for survey, and the sampling approaches adopted (e.g., distribution and density of sampling points, size and nature of specific features targeted for scat searches).

Survey objectives predominantly focused on inventory goals, such as determining the 'point in time' distribution and population status of pine martens at a state-wide or local scale (Table 12.1). Some researchers also pursued secondary objectives such as assessing habitat selection (Velander 1983, Strachan et al. 1996). Bright et al. (1995*a*) used scat surveys to determine the influence of woodland area and isolation of woodland patches on marten distribution. Some authors attempted to use variations in the abundance of marten scats to distinguish between established and non-breeding populations (e.g., Balharry

Table 12.1. A review of scat-based surveys of pine marten distribution, status, and abundance in Europe.

Author(s)	Geographical extent	Coverage	Objectives	Period	Duration	Number of transects	Transect length (km)	Density and arrangement of sampling points
Velander (1983)	292 10x10 km squares[a] in Scotland, England and Wales	National	Distribution and status	1980–1982 continuous	20 months	313	0.7–2.0	Mean of 1.0 transect per 10 x 10 km square in Scotland, and 1.9 per 10x10 km square in England and Wales.
Strachan et al. (1996)[b]	144 10 x 10 km squares in England and Wales	National	Distribution and status	1987–1988 continuous	19 months	896 (of which 212 were resurveyed)	2.0	Mean of 6.22 transects per 10x10 km square.
Clevenger (1993)	Minorca and Majorca Islands, Spain	Island-wide	Distribution and status	March–December 1990	10 months	39 (20 on Minorca; 19 on Majorca)	0.5–Minorca 2.5–Majorca	1 transect per 2x2 km square on Minorca; 1 transect per 5x5 km square on Majorca.
Bright and Harris (1994)	Parts of northern England	Local	Status	October & November 1993	< 8 weeks	91	2.0	Transect density notspecified, although similar to Strachan et al. (1996) above. Transects usually clumped 3 or 4 together, with each about 1 km apart.
McDonald et al. (1994)	39 10x10 km squares in mid and north Wales	Local	Distribution	June–October 1994	4 months	257	2.0	Mean of 6.1 transects per 10x10 km square. Transects not grouped closely together, but spaced 1–2 km apart.

Table 12.1. Continued.

Author(s)	Geographical extent	Coverage	Objectives	Period	Duration	Number of transects	Transect length (km)	Density and arrangement of sampling points
Bright et al. (1995*a*)	Ten 10x10 km squares in the Kielder Region of England-Scotland borders	Local	Determine status	May and June 1995	2 weeks	115	2.0	Mean of 11.5 transects per 10x10 km square. Transects not grouped closely together, but spaced 1–2 km apart.
Bright et al. (1995*b*)	Highland Region, north-west Scotland (mainland)	Local	Autecological study	October & November 1995	< 8 weeks	135 (in 63 woodlands)	2.0	Maximum of 3 transects per woodland. Transects grouped together “to avoid them falling between pine marten territories where scats may not be deposited”.
Balharry et al. (1996)	82 4–5 km^2 ‘search areas’ covering parts of Scotland	Local	Map range expansion	May–October 1994	6 months	306	1.0	Four separate 1 km transects in each of 82 search areas of 4–5 km^2.
Bright and Smithson (1997)	South–west Scotland	Local	Distribution and population expansion	1995–1996	not specified	191	2.0	Six 2 km transects searched in each discrete forest block or larger forested area sub-divided on basis of rivers that form territory boundaries.

[a]A 10x10 km square is a square mapping unit with an area of 100 km^2.
[b]This survey was completed in 1988 but not published until 1996, after some subsequent surveys were published. Pre-publication drafts were made available to some authors of subsequent surveys; hence some references in the text may not appear chronological.

et al. 1996, Bright and Smithson 1997). True monitoring, involving repeated inventories to assess changes in population status and distribution (e.g., Strachan et al. 1990), was never an objective stated by survey authors. However, some authors inferred changes in range, status, or abundance by comparing the results of successive surveys organized by different authors (Bright and Harris 1994, McDonald et al. 1994).

Among the surveys considered in this review, only Clevenger (1993) attempted to achieve complete geographical coverage of a survey area. The other studies surveyed marten distribution within 10 × 10 km squares selected on the basis of locations of previous sightings or carcass collections (e.g., Velander 1983, Strachan et al. 1996). Because of the large extent of target areas, some authors delimited survey areas on the basis of concentrations of presumed suitable habitat, such as extensive woodland cover (e.g., McDonald et al. 1994, Balharry et al. 1996).

The selection of habitats chosen for survey reflects the predominant view that pine martens are animals of mature woodland and forest (Balharry 1993). However, some authors also searched non-wooded habitats (Table 12.2), which may be especially relevant in the British Isles, where marten populations have survived despite extensive deforestation that reduced woodland cover to only 4% of the land area by the early 20th century (currently 12%) (Anonymous 1998). Gradual deforestation in England created low and fragmented woodland cover that has existed for nearly 2,000 years (Rackham 1990). Under such conditions, martens probably faced strong pressure to exploit alternative three-dimensional habitats, enabling populations to survive in the absence of woodland and forest. Such adaptation may have left a legacy of habitat use by martens, persisting to the present day. There is abundant anecdotal evidence of martens occupying, or even favoring, open, rocky landscapes in Britain (e.g., Macpherson 1892, Corbet 1966, Hurrell 1968, Webster 2001). However, this possibility has not been reflected in the design of most scat surveys. The choice of habitats surveyed is not consistent across studies (Table 12.2). Some surveys encompassed a wide range of wooded and unwooded habitats, while others focused heavily on commercial conifer forests with transects concentrated in thicket stage plantations where "martens are likely to concentrate their activity" (Balharry 1993). Commercial conifer plantations in Britain are more extensive (Anonymous 1998) and are aggregated in larger blocks than other woodland types; thus, this habitat best satisfies the requirements of surveys that target areas of high forest cover, with the result that other woodland types may be less well represented in surveys. Most surveys involved sampling in a limited range of habitats, yet authors often drew wider inferences about presence or status of martens.

Table 12.2. Habitats sampled and specific features searched during scat surveys.

Author(s)	Habitats sampled	Transect characteristics
Velander (1983)	Predominantly mixed conifer plantations, but also other woodlands, open moorland, pasture, coastal, and scrub.	Trails and paths.
Strachan et al. (1996)	Mainly woodland, but also pasture, moorland, rock outcrops, crags, and scrub.	Trails, paths, and forest roads.
Clevenger (1993)	Pine forests, Holm oak woodlands, and forest or shrub cover.	Unpaved roads and trails that traversed the largest area with Mediterranean shrublands.
Bright and Harris (1994)	Woodland and forest.	Trails, paths, and woodland edges.
McDonald et al. (1994)	Predominantly woodland and forestry plantations.	Woodland trails, paths, woodland edges, streams within woodland, and crossing points between woodlands.
Bright et al. (1995*a*)	Commercial conifer forest and woodland.	5-m-wide woodland trails only, chosen to pass topographical intersections (e.g. a trail over a stream).
Bright et al. (1995*b*)	Woodland.	A range of trails and paths through woodland, and woodland edges. Transect routes selected to pass through habitats and past landscape nodes.
Balharry et al. (1996)	Woodland.	Woodland trails (ideally of dirt or stone, not grass-covered), chosen to include intersections with streams or other trails and to exclude areas with high vehicle or human use.
Bright and Smithson (1997)	Commercial conifer forest.	Forest trails (5 m wide).

The reliability of scat surveys depends upon sampling strategies that coincide with sites where scats of martens are deposited. Adult pine martens in captivity each produce an average of 5 scats per day (T.B. personal observation and M. Noble, personal communication). Since martens are believed to mark trails with their scats (Lockie 1964, Pullianen 1982), transects are typically surveyed along such features (Table 12.2). Because martens may mark most heavily where their own trails cross man-made trails or other linear features such as streams, some surveyors also selected transects to include such intersections. Two studies searched transects along woodland edges, using the assumption that martens might not mark intensively along trails where woodlands are sparsely vegetated at ground level (e.g., Bright and Harris 1994). Bright et al. (1995*b*) suggested that scats were more likely to be found on wider trails within woodland; thus, 2 surveys limited the selection of transects to 5 m-wide trails in woodland/forest, and all narrower woodland/forest paths and trails, woodland edges, and non-wooded habitats were excluded. Thus, there has been some inconsistency resulting from *a priori* assumptions regarding habitat associations and behaviors of martens in many previous surveys.

Trail-marking behavior may be a particular feature of strongly territorial populations of martens (Balharry et al. 1996). However, survey protocols have not considered the possibility that martens may not defecate on trails and paths where populations are low and, consequently, the need for territorial marking is greatly reduced. Scat surveys involve searching the ground, despite that martens spend much of their time resting or active above ground (Birks 2002). An unknown proportion of scats may be deposited in ways that reflect this three-dimensional lifestyle. In the Netherlands, marten scats are concentrated on branches or tree bases beneath arboreal dens in the holes made by black woodpeckers (*Dryocopus martius*); therefore, surveyors concentrate their search for fresh scats beneath woodpecker holes (Kleef 1997). The untested assumption that scats of martens occur disproportionately on man-made trails is a weakness common to most surveys. Concerns about detection of scats by human surveyors searching only accessible features such as trails could be addressed by involving trained dogs, which use their scenting ability to search more representatively than humans (Smith et al. 2001).

Scat surveys for martens have used transect lengths of 0.5–2.0 km, with authors selecting transect length in response to local conditions and survey goals. Several authors justified their choice of transect length by estimating the probability of detecting scats over different lengths. For example, Velander (1983) reported that scats were detected within the first 500 m on 81.2% of positive transects, within the first 700 m on 94.1%, and within 1 km on 98.6%. On this basis she adopted 700 m as the minimum and 1 km as the preferred transect length in her study. However, most subsequent surveys have used the 2 km transect approach adopted by Strachan et al. (1996) on the basis that Velander's (1983) 1 km transects were too short to detect martens at low population densities. The method based on groups of 4 1-km transects adopted by Balharry et al. (1996) was tested in the core of the range of martens in Wester Ross, Scotland. The probability that at least one scat would be found was 85.3% if only 1 km was searched, and 97.8% if 2 km were searched. Bright and

Smithson (1997) reported that the probability of detecting scats reached an asymptote after 8 km of transect. Thus, they concluded that their choice of 6 2-km transects was adequate for detecting presence of martens. No validation of the effect of transect length on probability of scat detection has been attempted outside Scotland. Variations in transect length among surveys matter little where simple detection of marten occurrence is the goal. However, difficulties arise where authors seek to compare results or infer trends from independent surveys.

Some authors argued that the spacing of transects was important to ensure that they were not located between marten territories. For example, Bright and Harris (1994) suggested that Strachan et al. (1996) might have missed marten sites because most transects were spaced more than one territory diameter apart. To overcome this effect, some subsequent surveys have clumped or spaced transects only 1–2 km apart, which has the potential drawback of repeatedly sampling the same individual.

3. SCAT IDENTIFICATION

Confidence in the results of scat-based marten surveys is dependent on the correct identification of marten scats. Caution is needed because feces from foxes (*Vulpes vulpes*), polecats and polecat-ferrets (*Mustela putorius*), mink (*Mustela vison*), and stoats (*Mustela erminea*) may appear similar to those of martens (McDonald et al. 1994, Balharry et al. 1996). We reviewed the approaches adopted by different surveys to ensure accurate identification of marten scats. We also considered new genetic evidence for assessing the accuracy of scat identification in the field.

Several authors have sought to build confidence in their methodology by specifying the criteria applied when identifying scats, though the degree of rigor varies considerably (Table 12.3). Some surveyors also recorded additional evidence, such as clear footprints, to indicate marten presence (e.g., Strachan et al. 1996). Some studies refer to the distinctive sweet, musky odor as being critical to the correct identification of marten scats. As a result, some surveys specified that only fresh scats (a few days old) that had not lost their smell were taken as evidence of marten presence (e.g., Bright and Smithson 1997). McDonald et al. (1994) suggested that Strachan et al. (1996) may have misclassified scats from other carnivores as those of martens, leading to “an exaggerated estimate of marten abundance”. Those 2 surveys, separated by a period of 6 years, offered different conclusions about the status of martens in Wales. Strachan et al. (1996) concluded that the population was extant and “static or showed a very moderate spread”, and McDonald et al. (1994) con-

Table 12.3. Criteria applied to the identification of pine marten scats during surveys conducted in Europe.

Author(s)	Identification criteria
Velander (1983)	Scats were "examined according to size, texture and odour to ensure that they were those of martens".
Strachan et al. (1996)	No criteria specified, although variations in size, shape and color were described.
Clevenger (1993)	No criteria specified: "Faeces that might have been confused with those of weasel *Mustela nivalis* or feral cat *Felis catus* were discarded".
Bright and Harris (1994)	"Marten scats were recognised by their distinctive sweet odour (…like cranberry sauce) and frequent characteristic long, twisted shape; they were not recognised on the basis of shape alone"
McDonald et al. (1994)	As for Bright & Harris (1994) above. "Since single scats cannot be classified as those of martens with total certainty, it was considered that several scats needed to be found on a transect to confirm that martens were present".
Bright et al. (1995*a*)	"Marten scats were recognised on the basis of both their distinctive odour and morphology".
Bright et al. (1995*b*)	"Scats were identified on the basis of both their distinctive sweat (sic) musky odour and morphology, being 8 mm in diameter and 40–80 mm long. They are also frequently, but not always twisted". "Because marten scat odour and morphology vary to some extent with diet, several scats need to be found at one site to reliably indicate marten presence".
Balharry et al. (1996)	"A fresh scat has a unique smell of marten. Older marten scats can be identified by size and shape although they overlap in size with stoat at one extreme and with fox at the other and shape is highly dependent on diet. Confusion may also occur with ferret and mink scats. Only those scats which were obviously marten were collected".
Bright and Smithson (1997)	Marten scats "were recognised by their morphology and sweat-musky (sic) odour". "Only fresh scats (a few days old) with characteristic odour were classified as being from pine martens. This avoided confusion with those of fox *Vulpes vulpes* or stoat *Mustela erminea* which overlap in morphology, but not in odour".

cluded that no viable populations remained, and that martens in Wales were on the brink of extinction.

Because of the variation in scat odor and morphology, some studies only inferred marten presence if several fresh scats were found on a 2 km transect (McDonald et al. 1994), or if at least 3 scats were found within a woodland site (Bright et al. 1995*b*). In their survey of the Kielder Region (northern England), Bright et al. (1995*a*) recorded 27 scats that had similar morphology to marten scats, but all lacked odor. Moreover, some were found in characteristically marten-like groups, and appeared too fresh to have lost the pungent odor typical of scats produced by other carnivores. The authors concluded that they "might therefore have been produced by martens, but we cannot be certain". These scats might have been accepted as more certain evidence of martens by other studies with more inclusive criteria (e.g., Strachan et al. 1996). Clearly, differences in identification rigor between surveys preclude objective comparison of results.

The assumption that field identification of marten scats is accurate has only recently been tested by the application of DNA techniques. Such techniques are currently too expensive to be applied widely as an aid to surveys, but they can help to validate new or established field protocols (e.g., Hansen and Jacobsen 1999). A genetic study by Davison et al. (2002) revealed that 3 experienced surveyors misclassified 18% of fresh 'marten' scats (n = 56) collected in the field in Scotland. Based on DNA evidence, misclassified scats in this sample were from red foxes. DNA was successfully extracted and amplified from only 53% of fresh scats collected, and this has implications for the wider application of this approach to the verification of scat identity. Individual surveyor misclassification varied (9–29%) and this level of error is conservative because surveyors were both experienced and aware that their skills were being evaluated. Regardless, 2 surveyors misclassified scats that they had categorized as 'certain' marten on the basis of morphology and odor. The surveyor who performed most reliably (9% error) in Scotland misclassified all scats (n = 12) collected from the sparser populations of martens in England and Wales. This new genetic evidence of a significant error factor undermines the central assumption on which all scat surveys have been based.

4. VARIATION IN ABUNDANCE AND DETECTABILITY

We evaluated the use of scats for determining presence and population status of martens by reviewing patterns of abundance revealed by surveys. We also considered the role of seasonal factors in influencing scat abundance. We assessed attempts by some authors to relate scat abundance to marten residency status, and we examined the inferences drawn by authors where no scats were found.

Following Lockie's (1964) pioneering work, authors have noted temporal variations in the abundance of scats and have suggested possible explanations. Most have noted that scat numbers on transects are highest in summer, and suggest that surveying outside this period may be problematic (Bright et al.

1995*b*). Velander (1986) reported that scat density on a series of forest trails varied greatly from month to month, being more than 100 times greater in July (12 scats/km) than in January (0.1 scats/km). Clearly, seasonal variations may have a profound influence on the results generated by surveys. Where martens are scarce this may lead to conclusions that the species is absent at sites that would prove positive at other times of year. This effect was reported by Strachan et al. (1996) after an absence of scats was observed on transects in areas of sparse marten populations that yielded scats when resurveyed a few months later. Some surveyors have interpreted changes in scat abundance as evidence of seasonal range shifts (e.g., Velander 1983, Strachan et al. 1996). However, it is likely that seasonal changes in marten numbers, general activity levels, and the intensity of social marking behavior also contribute to the observed pattern (Helldin and Lindström 1995). Certainly, the observed pattern fits the prediction that marking should be most intense during the summer mating season (July/August), when adults socialize actively and the population is increased by the presence of young. Conversely, pine martens greatly reduce their activity during winter months (Zalewski 2000) when many scats are probably deposited at resting sites. However, most wide-scale and some local surveys have not concentrated on the ideal summer months (Table 12.1). As a consequence, a significant proportion of survey effort has occurred when the available scats were predictably scarce, which influences survey results, especially at low population densities.

A feature of all scat-based surveys has been the sizeable proportion of negative survey transects or search areas. These pose a problem of interpretation for authors who may be tempted to infer that martens are absent. Survey authors have conceded that it is impossible to prove that pine martens are absent from an area (e.g., Bright and Harris 1994), and some have taken other evidence (e.g., footprints, reported sightings, interviews with local naturalists) into account before drawing conclusions. The risks of inferring absence falsely from negative scat surveys are emphasised by the work of Velander (1983), who recorded 32 10 x 10 km squares in Scotland that were negative on the basis of scat surveys, yet they yielded carcasses or sightings of martens (these 'false negatives' comprised 21.3% of the total number of positive 10 x 10 km squares). In Bright and Smithson's (1997) survey in south-west Scotland, no scats were found at several locations where other recent evidence had indicated that martens were present. The very limited results in England and Wales (see Table 12.4) occurred when other evidence (footprints, reported sightings and carcasses) indicated that martens were present. Following interviews with local naturalists, Velander (1983) concluded that 4 main marten populations were still present in England and Wales, despite observing no scats during field

Table 12.4. Scat densities recorded during surveys of pine martens.

Author(s)	Geographical extent	Range of scat densities recorded on 'positive' transects	Proportion of transects or sampling areas with no field evidence of martens
Velander (1983)	Scotland	1–7 scats/500 m (mean 2.64 ± 0.21)	42.8% (n = 173)
Velander (1983)	England & Wales	No positive transects	100% (n = 36)
Strachan et al. (1996)	England & Wales	1–10 scats/2 km (mean 0.54 ± 0.04)	88.8% (n = 896)
Clevenger (1993)	Minorca & Majorca, Spain	No data (searches terminated when first scats found)	
Bright and Harris (1994)	England	1 scat/2 km (only two scats found in entire survey)	97.8% (n = 91)
McDonald et al. (1994)	Wales	1 scat/2 km (only three scats found in entire survey)	98.8% (n = 257)
Bright et al. (1995a)	England	No certain marten scats found, though possible marten scats found on 8 transects at rates of 2–4/500 m.	100% (n = 115)
Bright et al. (1995b)	Scotland	Mean distance walked to find three scats was 1.3 km±0.7km.	39.1% (n = 63)
Balharry et al. (1996)	Scotland	1–27 scats/1 km	58.8% of all transects (n = 306) 41.5% of search areas (n = 82)
Bright and Smithson (1997)	Scotland	Mean 5.4 ± 0.24 scats per 'breeding potential marten area'[a] (total 12 km transect searched per area); mean 1.8±0.37 scats per 'occupied potential marten area'[b].	Not stated

[a]These areas, with higher scat densities, generated sightings of female martens with young.
[b]These areas, with lower scat densities, generated less evidence of reproducing martens.

surveys. She explained the failure of scat surveys to detect these populations as "due presumably to the difficulties in finding evidence of martens when in low numbers" (Velander 1983). Other authors have placed greater confidence in scat data alone, even where the animals are scarce. McDonald et al. (1994) argue that the intensity of marking with scats is density dependent. They speculate that where martens are scarce, population densities would not be low in all areas, but would be high enough locally in some areas for scats to be observed during surveys. On this basis, and because few marten scats were found in surveys of both England and Wales, authors concluded that pine martens were on the brink of extinction with no viable populations remaining (Bright and Harris 1994, McDonald et al. 1994). This pessimistic assessment contrasts markedly with authors who have interpreted scat abundance data more cautiously, and have considered other evidence (e.g., Velander 1983, Strachan et al. 1996). Clearly, there are circumstances where it is misleading to base status assessments exclusively on the basis of scat occurrences.

Our own work in Wales has revealed a further influence that must reduce the detectability of marten scats where they are scarce. Foxes were observed to destroy, by aggressive scratching, several scats (from captive martens) that had been placed on forest trails to stimulate counter-marking by wild martens. Dor beetles (*Geotrupes* sp.) were observed to remove and bury scats of martens, and great black slugs (*Arion ater*) were observed to completely consume fresh scats within as few as 48 hrs (Braithwaite et al., The Vincent Wildlife Trust, Ledbury, UK. unpublished data).

Additional to determining presence of martens on the basis of scats, some authors have used variations in scat abundance to determine residency (Balharry et al. 1996, Bright and Smithson 1997). However, no empirical evidence supports the assumption that areas with fewer scats contain only dispersing or non-breeding marten. Nor did these attempts to define marten population status by reference to relative scat abundance account for seasonal influences on scat deposition rates (Velander 1986).

Some authors have tried to define thresholds of scat abundance as indicators of relative, but not absolute, absence of martens. For example, Bright et al. (1995b) considered that martens were absent from, or not regularly using, a woodland if fewer than 3 distinctive scats were found. However, the same survey team adopted a different criterion elsewhere in Scotland where areas with 1–3 scats (mean 1.8 over 12 km searched) were regarded as occupied by marten (Bright and Smithson 1997). Such arbitrary assumptions seem unwise in the absence of a clear understanding of the relationship between scat abundance and the numbers of martens.

5. CONCLUSIONS AND RECOMMENDATIONS

The revelation that experienced marten researchers misclassify fresh scats undermines all confidence in the scat survey method as it is currently applied. We recommend that the technique should not be used for any survey goals in the absence of genetic verification of scat identity, especially in areas where martens occur at low densities. It might be argued that scat surveys may have a role in determining presence of martens where independent and incontrovertible evidence indicates that they are common, but this circular argument would seem to render the technique irrelevant.

Survey methods and objectives were questionable because all were based on assumptions that surveyors could identify scats accurately. Regardless of this major flaw, methodologies have been based on assumptions that appear unreasonable in the absence of thorough field-testing. Scat survey protocols have not been validated across the full range of seasonal, habitat, and population conditions. Notably, protocols have never been adequately tested and shown to be reliable in areas where martens occur at low densities. We recommend that future application of scat surveys for inventory and monitoring goals should be preceded by a program of practical and statistical validation. We also recommend that inferences drawn from future surveys should be limited to the habitats sampled.

The field relationship between scat abundance on transects and marten numbers has not been established. Consequently, it is unsafe to use scat abundance data for inferring marten abundance, or for monitoring population trends. Particular problems of interpretation arise where scats are scarce or absent in areas known, from other evidence, to be occupied by martens. Few conclusions can safely be drawn where no marten scats are found, beyond the possibility that the animals are scarce in such areas. Where martens and their scats are apparently common, the influence of identification errors prevents the reliable use of scat abundance indices for assessing abundance and population trends. Thus, we recommend that genetic verification be included as an essential component of all scat surveys. Nevertheless, even with genetic verification, scat abundance indices could be meaningless if seasonal variation in scat deposition patterns is not controlled for. These issues can only be addressed through behavioral studies of martens across a range of season, habitat, and population conditions.

Even prior to the genetic confirmation of significant surveyor error (Davison et al. 2002), others have warned against the use of marten scat surveys, including those advising the UK Government on future mammal monitoring. Toms et al. (1999) warned that “In areas with low population densities or containing only transitory individuals, the degree of scatting is likely to be greatly reduced, making it difficult to apply a transect approach based on field signs. Territorial behavior in other mustelids has been shown to break down altogether at low population densities potentially making this method ineffective in some regions". Similarly, Macdonald et al. (1998) warn that "scat surveys may be unreliable at low population densities where they are less territorial".

Scat surveys are unreliable without genetic verification; therefore, conclusions drawn primarily from scat data by the authors of surveys reviewed in this paper are questionable. In particular, the use of scat abundance data to infer that no viable populations remain in England (Bright and Harris 1994) and Wales (McDonald et al. 1994) is unsupportable. There is clearly a need to develop and refine approaches to detecting and monitoring pine martens. This need is especially great where the species is scarce and difficult to detect. Under such circumstances, we recommend the systematic deployment of a range of methods such as sighting surveys (Messenger and Birks 2000), camera traps (Zielinski and Kucera 1995), tracker dogs (Smith et al. 2001), hair snagging stations (Messenger and Birks 2000), or track plates (Zielinski and Kucera 1995).

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