Techniques and Technology Article

Comparing Scat Detection Dogs, Cameras, and Hair Snares for Surveying Carnivores

ROBERT A. LONG,[1,2] *Vermont Cooperative Fish and Wildlife Research Unit, University of Vermont, Burlington, VT 05405, USA*

THERESE M. DONOVAN, *United States Geological Survey Vermont Cooperative Fish & Wildlife Research Unit, University of Vermont, Burlington, VT 05405, USA*

PAULA MACKAY, *University of Vermont, Burlington, VT 05405, USA*

WILLIAM J. ZIELINSKI, *United States Department of Agriculture Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521, USA*

JEFFREY S. BUZAS, *Department of Mathematics and Statistics, University of Vermont, Burlington, VT 05405, USA*

ABSTRACT Carnivores typically require large areas of habitat, exist at low natural densities, and exhibit elusive behavior—characteristics that render them difficult to study. Noninvasive survey methods increasingly provide means to collect extensive data on carnivore occupancy, distribution, and abundance. During the summers of 2003–2004, we compared the abilities of scat detection dogs, remote cameras, and hair snares to detect black bears (*Ursus americanus*), fishers (*Martes pennanti*), and bobcats (*Lynx rufus*) at 168 sites throughout Vermont. All 3 methods detected black bears; neither fishers nor bobcats were detected by hair snares. Scat detection dogs yielded the highest raw detection rate and probability of detection (given presence) for each of the target species, as well as the greatest number of unique detections (i.e., occasions when only one method detected the target species). We estimated that the mean probability of detecting the target species during a single visit to a site with a detection dog was 0.87 for black bears, 0.84 for fishers, and 0.27 for bobcats. Although the cost of surveying with detection dogs was higher than that of remote cameras or hair snares, the efficiency of this method rendered it the most cost-effective survey method. (JOURNAL OF WILDLIFE MANAGEMENT 71(6):2018–2025; 2007)

DOI: 10.2193/2006-292

KEY WORDS black bear, bobcat, carnivore, detection dog, fisher, *Lynx rufus*, *Martes pennanti*, noninvasive, survey, *Ursus americanus*.

Terrestrial carnivores often possess characteristics (e.g., large area requirements, low densities, elusive behavior) that render them difficult to study. Noninvasive survey methods enable researchers to study such animals across large areas. Remote cameras and various hair snare devices, for example, can be used to confirm a species (or, in some cases, an individual) at a given site (McDaniel et al. 2000, Moruzzi et al. 2002, Heilbrun et al. 2003, Wasser et al. 2004, Weaver et al. 2005, Zielinski et al. 2006). More recently, detection dogs have been used to locate fecal (scat) samples from free-ranging carnivores, thus confirming species' presence and also providing the opportunity to collect fecal DNA and hormone information for other analyses (Smith et al. 2001, 2003; Wasser et al. 2004; Long et al. 2007). Scat detection dogs do not require the use of attractants (thus potentially minimizing sampling biases) and allow sampling to occur quickly and efficiently across the region of interest. Despite growing interest in this method, few studies (Smith et al. 2001, 2003, 2005; Wasser et al. 2004; Harrison 2006) have quantitatively explored its effectiveness. Further, no study to date has compared the effectiveness of scat detection dogs to that of other survey methods for sampling multiple species or for detecting carnivores in the densely forested regions of the northeastern United States.

Our objective was to compare the effectiveness and cost of 3 noninvasive techniques—detection dogs, remote cameras, and hair snares—for detecting black bears (*Ursus americanus*), fishers (*Martes pennanti*), and bobcats (*Lynx rufus*) across a primarily forested, topographically complex region.

STUDY AREA

Our study area comprised the entire state of Vermont (24,963 km^2), as well as several sites located immediately west of central Vermont's border with New York, USA. Additional study area details can be found in Long et al. (2007).

METHODS

Survey Methods and Design

Detection dog surveys.—We conducted detection dog surveys at 168 sites distributed throughout our study area. Detailed descriptions of survey site selection, detection dog training, survey protocols, and criteria for assigning a species detection (or nondetection) at each site can be found in Long et al. (2007). Briefly, we made an attempt to locate sites $\geq$5 km apart, and we surveyed a 2-km, diamond-shaped transect at each site. Detection dog teams (i.e., dog, handler, orienteer) searched along the transect line, and we used scats collected inside the diamond-shaped transect, or $\leq$100 m to the outside of the transect line (i.e., the detection zone; Long et al. 2007), to establish target species detections or nondetections at each site.

Remote camera surveys.—We conducted camera surveys at a randomly selected subset of the 168 sites ($n = 74$; 44% of total sites; 50 in 2003, 24 in 2004) searched by detection dog teams (Long et al. 2007). We deployed a single remote

[1] *E-mail: robert.long@coe.montana.edu*
[2] *Present address: Road Ecology Program, Western Transportation Institute, Montana State University, P.O. Box 1654, Ellensburg, WA 98926, USA*

camera unit (sensor and camera) at each of these sites. Although higher camera densities have been employed in other studies (Moruzzi et al. 2002, Sequin et al. 2003, Campbell 2004), we were interested in comparing methods using what we considered to be minimum effort. We placed camera units beneath forest cover and away from roads and trails. In 2003, we used Trailmaster 1500 (active) and 550 (passive) sensors (Goodson & Associates, Inc., Lenexa, KS), paired with Yashica (Kyocera Inc., Kyoto, Japan) and Canon (Canon Inc., Tokyo, Japan) camera units that were factory modified to interface with the sensors. External wires connected the sensors to the cameras. In 2004, we deployed CamTrakker Original passive camera-sensor units (CamTrak South, Watkinsville, GA) consisting of a camera and sensor housed in a single waterproof case. We loaded cameras with 24-exposure, 200-ASA color print film, and the time and date of exposure were automatically recorded on each frame. Based on previous studies of similar species (R. Schlexer, United States Department of Agriculture [USDA] Forest Service, Pacific Southwest Research Station, personal communication), we programmed cameras for a 5-minute delay between photos to minimize the chance that a single animal would be the subject of an entire roll of film.

We deployed camera units during the detection dog team's first visit to a site. At each camera site, we selected a large tree to serve as the target for the sensor and camera. In 2003, we applied a commercial trapping lure (Gusto, Minnesota Trapline Products, Pennock, MN)—known to be effective for attracting multiple carnivore species in both the West (Zielinski et al. 2005) and the Northeast (Gompper et al. 2006)—in both a shallow hole and on woody debris at the base of the target tree. Further, to attract black bears, we hung a small nylon bag containing fish food pellets and molasses (C. Olfenbuttel, Cooperative Alleghany Bear Study, personal communication) at a height of approximately 3 m and within 10 m of the target tree but not within range of the sensor. In 2004, we added 2 pieces of raw chicken to the target tree in an attempt to increase visitation by fishers. We left camera units in place for 14 days, and resulting exposures were developed at a local photo lab. We recorded a target species' detection if an identifiable photo was taken during the survey period.

Hair snare surveys.—At each camera station, detection teams also deployed 2 hair snares composed of a 10×10 cm carpet pad with approximately 10 2.5-cm nail-gun nails pushed through the pad (McDaniel et al. 2000; J. Weaver, Wildlife Conservation Society, personal communication). These nails were originally packaged in a coil connected by wires which, when clipped apart, created 4 small (5-mm) barbs that facilitated the snagging of hair. We attached one snare to the target tree 40–45 cm above the ground (McDaniel et al. 2000; J. Weaver, personal communication). We attached the second snare at the same height to a second tree within 10 m of the target tree. We placed 5 mL of scent lure in the center of each snare pad, which we then sprinkled with dried catnip. This scent lure was designed specifically for felids but has also been shown to be effective for ursids (J. Weaver, personal communication). We suspended a metal pie pan with monofilament line from a branch at a height of approximately 1 m to serve as a visual attractant. We checked hair snares when we removed cameras, after a mean duration of 14 days. We stored collected hairs in paper envelopes in a cool, dry location for future genetic analysis.

We recorded hair snare detections under 1 of 2 conditions. We recorded a black bear detection on a site if a hair snare captured copious quantities of coarse, black hair, sometimes accompanied by additional hairs on the snare tree. We sent all other hair samples collected from snare pads to Wildlife Genetics International (Nelson, BC, Canada) for species identification. DNA was extracted from hair samples using QIAGEN's DNeasy Tissue Kits (Qiagen Inc., Valencia, CA). Whenever possible, 10 guard hair roots were used for analysis. The species test was identical to that described in Long et al. (2007) for DNA extracted from scats. We recorded a target species detection if hairs found on the snare pad were confirmed via genetic analysis to be from that target species.

Comparing Method Effectiveness

We evaluated method effectiveness by comparing a number of performance metrics calculated for each technique. These metrics included raw detection rates (i.e., the proportion of sites where a target species was detected by a single survey with a given method) on sites surveyed by all methods; the number of unique detections (i.e., the no. of times a detection by a given method represented the only detection of that species at the site; Campbell 2004); and the overall probability of detection (p; the probability that the species was detected, given that it was present at a site; MacKenzie et al. 2002). Probability of detection can be estimated from detection–nondetection data collected during repeat surveys at a subset of sites (MacKenzie et al. 2002). Further, assuming surveys and methods are independent, and that the survey duration is defined (e.g., a single dog visit, a 14-d camera survey), surveys conducted at a given site via different methods can constitute repeat surveys. Thus, we used data from all sites to calculate method-specific estimates of detectability, with each site visited 1, 2, or 3 times by a detection dog team and a subset of sites surveyed additionally with remote cameras and hair snares.

For each site, we compiled a detection history based on 5 independent surveys corresponding to 3 dog surveys, one camera survey, and one hair snare survey. This occupancy modeling technique can accommodate sites lacking ≥ 1 survey (e.g., sites where we did not deploy a camera or where we conducted only 2 dog surveys). For example, a site detection history of "10011" indicated that the target species was detected during the first dog survey, not detected during the second and third dog surveys, and detected by both the camera and hair snare surveys. In contrast, a history of "1. . .10" indicated that the target species was detected during the first (and only) dog survey, detected by the camera survey, and not detected by the hair snare survey. We used the encounter histories and the occupancy estimation option in the program MARK Version 5.1 (White and Burnham 1999) to estimate the probability of detecting each target species (given presence) during a single survey (i.e., one dog-team visit, one 14-d camera survey, or one 14-d hair snare survey) of a site with a given technique.

Assuming detections are independent across methods and surveys, detection probabilities can be accumulated to estimate the probability of detecting a species given the use of >1 method or with multiple surveys (Campbell 2004). For example, for m detection methods with detection probabilities of $p_1, p_2, \ldots, p_m$, and $n_1, n_2, \ldots, n_i$ surveys, the overall probability of detecting a target species by ≥ 1 method during one survey is calculated as:

$$P = 1 - \prod_{i=1}^{m} (1 - p_i)^{n_i}$$

We used this formula to compare the number of surveys required using each method, or a combination of methods, to achieve a specified probability of detection.

Comparing Method Cost

We tracked equipment and supply costs incurred over the 2 field seasons, enabling the calculation of total costs and mean expense for each survey method, as well as associated labor and transportation costs. We used costs per transect for each method to estimate the cost of conducting a hypothetical field survey of 60 sites with new equipment and newly trained personnel, followed by a second hypothetical survey of 60 sites conducted with the same equipment and experienced personnel.

We estimated costs for scenarios that involved: 1) leasing or 2) purchasing a detection dog, using 2005 pricing. We assumed that only a single detection dog team was employed, and that each site survey was completed in a single field day. Estimates for purchased dogs included the cost of dog food during the off-season (i.e., food for 365 − 60 − 60 d = 245 d). We did not include other off-season maintenance costs (e.g., housing) as such expenses are highly dependent on the specific situation. We based the costs of DNA analyses on testing an average of 2 scats per site. This expense will obviously vary with the number of scats located and the project's objectives.

The remote camera scenario included deployment of a single camera unit for 14 days at each site, with no revisits or rebaiting. We assumed initial camera site setup would require, on average, 0.75 field days (i.e., 4 sites in 3 d) and that camera removals would require, on average, 0.67 days (i.e., 4.5 sites in 3 d). We estimated all labor costs using a pay rate of $10 per hour.

To estimate costs for hypothetical hair snare surveys, we presumed that deployment, retrieval, and transportation expenses would be similar to those for the remote camera scenario. Cost estimates associated with DNA analyses of hair samples were similar to those used in the detection dog scenarios, with an average of 2 samples tested per site.

RESULTS

During May–August 2003 and 2004, 5 detection dog teams surveyed a total of 168 sites 220 times. Mean minimum nearest-neighbor distance between transects on adjacent sites was 6.9 km. Mean time required to survey a site with a detection dog was 4.1 hours ($n = 206$ surveys, SE = 0.10 hr, min. = 1.0 hr, max. = 10.8 hr).

Detection Dogs

Detection dog teams located 728 scats in 2003 and 868 scats in 2004 (see Long et al. 2007, table 2 for detailed scat results). Raw detection rates based on methods described in Long et al. (2007) were 57.1% (96/168 sites) for black bears, 61.3% for fishers (103/168 sites), and 12.5% for bobcats (21/168 sites).

Remote Cameras

We conducted remote camera surveys on 74 sites (49 in 2003, 25 in 2004). Camera or sensor failure occurred during 18 (24%) of these surveys and did not differ between years (Fisher's exact test, $P = 0.07$). Failures included cases in which the entire roll of film was faultily shot in 1 day, camera jamming, battery failure, chewed wiring, and camera displacement. We conducted valid camera surveys (i.e., those with no camera or sensor failures) for black bears at 59 sites and for fishers and bobcats at 56 sites. The discrepancy between these values was a result of 3 surveys that were incomplete due to camera or sensor malfunction but during which bears were detected before the camera became inoperable. Black bear and bobcat detection rates did not differ between years (Fisher's exact tests, $P = 0.53$ and $P = 0.55$, respectively); our 2003 fisher detection rate (8.8%; 3/34 sites with valid surveys) was lower than that of 2004 (36.4%; 8/22 sites with valid surveys; Fisher's exact test, $P = 0.017$). Given that our overall sample size was small, we report pooled results from both years for all species. In some comparisons, however, we also report fisher results from 2004 separately, as results varied significantly between years.

Over both survey seasons, we detected black bears at 14/59 sites with valid surveys (23.7%), fishers at 11/56 sites with valid surveys (19.6%), and bobcats at 3/56 sites with valid surveys (5.4%). If we included all 74 camera surveys (including those that failed) in the analysis, raw detection rates dropped to 18.9% for black bears, 14.9% for fishers (32.0% at 25 sites in 2004), and 4.1% for bobcats. Mean latency-to-first detection (the time from camera deployment until the first detection) was 5.9 days (SE = 0.9 d, range = 2–12 d) for bears, 6.6 days (SE = 1.6 d, range = 0–15 d) for fishers, and 6.0 days (SE = 2.1 d, range = 3–10 d) for bobcats.

Hair Snares

We deployed hair snares at 74 sites, and we collected 29 separate hair samples. We assumed 7 of these samples to result from contamination related to setup or removal procedures, and we lost one sample in transport. We attributed 6 samples to black bears based on hair color, morphology, and deposition characteristics (i.e., large quantities of hair also deposited on target tree). We sent the remaining 15 hair samples to the DNA lab for species identification; 4 were deemed to have insufficient DNA for

Table 1. Number of raw detections, unique detections, and probability of detection estimates by specific detection method for black bears, fishers, and bobcats. We conducted surveys during May–August 2003 and 2004 in Vermont and New York, USA.

Detection measure by method	Black bear			Fisher			Bobcat		
	No.	Rate		No.	Rate		No.	Rate	
Raw detections[a]									
Detection dog[b]	49	0.662		47	0.635		14	0.189	
Camera	14	0.189		11	0.149		3	0.041	
Hair snare	7	0.095		0	0		0	0	
	No.	Of uniques[d]	Of all[e]	No.	Of uniques	Of all	No.	Of uniques	Of all
Unique detections[c]									
Detection dog	32	0.914	0.653	35	0.972	0.745	11	0.846	0.786
Camera	1	0.029	0.020	1	0.028	0.021	2	0.154	0.143
Hair snare	2	0.057	0.041	0	0	0	0	0	0
	p	SE		p	SE		p	SE	
Probability of detection[f]									
Detection dog	0.872	0.063		0.842	0.075		0.274	0.175	
Camera	0.326	0.073		0.277	0.074		0.128	0.093	
Hair snare	0.079	0.038							

[a] No. of sites with detections and raw detection rates (detections/sites surveyed) by method for each target species on sites ($n = 74$) surveyed by all 3 methods. We included sites on which remote cameras malfunctioned. We included only detections recorded during the first detection dog visit.
[b] Includes only detections recorded during the first detection dog visit.
[c] No. of unique detections by method for each target species on sites surveyed by all 3 methods ($n = 74$).
[d] Unique detections as a proportion of all unique detections for a particular target species.
[e] Unique detections as a proportion of all detections for a particular target species.
[f] Probability of detecting (p) each target species by method. Probability of detection is the probability that the species will be detected (conditional on its presence) by a single survey. We generated estimates from data collected on all sites ($n = 168$), however, we deployed cameras and hair snares on a subset of these sites ($n = 74$). We did not include sites on which remote cameras malfunctioned ($n = 15$ for black bears, $n = 18$ for fishers and bobcats). Missing values indicate that the target species was not detected by that method.

analysis and another 4 failed during DNA extraction or amplification. Of those samples yielding a species identification, one was from a gray fox (*Urocyon cinereoargenteus*), one was from a black bear, and 5 were determined to be from either wolves (*Canis lupus* or *C. rufus*), domestic dogs (*C. lupus familiaris*), or eastern coyotes (*C. latrans*). Wolves and domestic dogs cannot be differentiated by mitochondrial DNA (mtDNA) because of their close or ongoing evolutionary relationships, and the potential interbreeding of coyotes and wolves can make distinguishing between their respective mtDNA problematic (D. Paetkau, Wildlife Genetics International, personal communication). We detected no bobcat or fisher hairs. We detected black bears by hair snares on 7/74 (9.5%) sites surveyed, and detection rates did not differ between survey seasons (Fisher's exact test, $P = 1.0$).

Comparing Method Effectiveness

At 74 sites where we employed all 3 methods, raw detection estimates varied substantially with detection method (Table 1). Detection dog teams were much more effective than either remote cameras or hair snares at detecting all 3 target species, with dogs detecting each of the target species at >3.5 times the number of sites as remote cameras, the second best method (Table 1). Hair snares failed to detect either fishers or bobcats. Detection dog teams were also responsible for the majority of unique detections of all 3 species (Table 1), yielding the only detections of bears at 65.3% of sites, fishers at 74.5% of sites, and bobcats at 78.6% of sites where they were respectively detected.

Our estimates for p (the probability that the target species will be detected during a single survey of a site, given presence; for method-species combinations where $p > 0$) ranged from 0.079 for detecting black bears with hair snares to 0.872 for detecting black bears with detection dogs. For both black bears and fishers, only one visit with a detection dog team was required to achieve >80% probability of detecting the species at a given site (Fig. 1). To detect bobcats with an 80% detection probability would have required 5 visits with a detection dog team (Fig. 1). By comparison, achieving the same detection probability with remote cameras as we did with dogs would have required 5 camera surveys for black bears and fishers (although only 3 surveys would have been required for fishers based on 2004 results) and 12 camera surveys for bobcats (Fig. 1). Lastly, to detect black bears with hair snares with an 80% detection probability would have required 20 hair snare surveys at a given site (Fig. 1). Because we did not detect fishers and bobcats with hair snares, we were unable to estimate the probability of detecting these species using this method.

Comparing Method Cost

Cost estimates for 2 hypothetical 60-site surveys averaged \$316 per site for a detection dog survey using a leased detection dog (Table 2). If we had specified that a dog be purchased at the outset of the project, the cost per site would have been \$257 (Table 2). We estimated remote camera

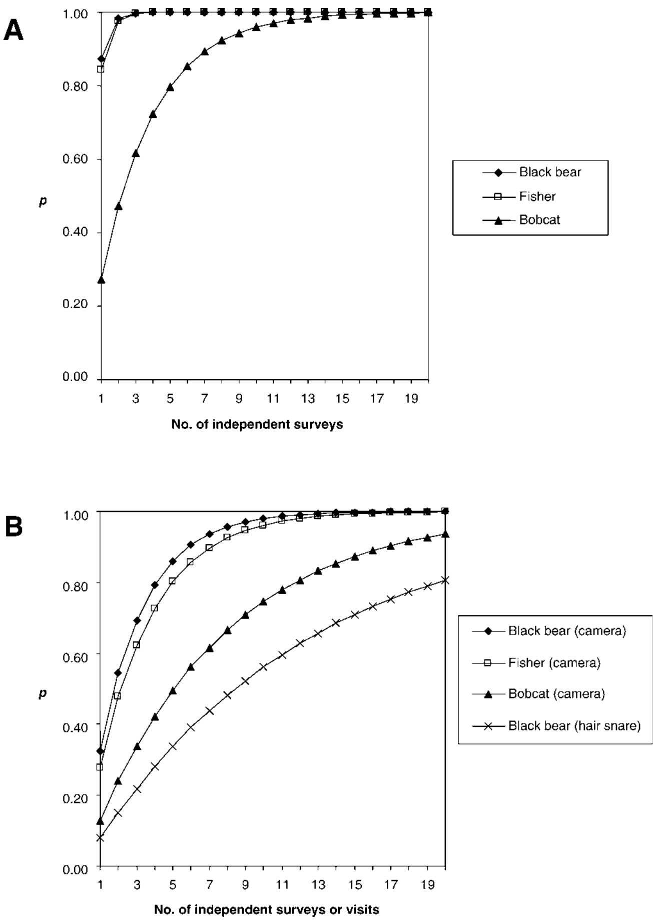

Figure 1. Probability of detecting (*p*) black bears, fishers, and bobcats (given presence) on sites in Vermont and New York, USA, with (A) detection dogs or (B) remote cameras or hair snares (black bears only) as a function of the number of independent surveys at a site, 2003–2004. Detectability curves for fishers and bobcats using hair snares are absent because we were unable to calculate detection probabilities for these species-method combinations.

surveys and hair snare surveys to cost $214 and $153 per site, respectively (Table 2).

DISCUSSION

Detection dogs were substantially more effective at detecting the 3 forest carnivores than remote cameras, which were in turn more effective than hair snares. Per site costs for detection dogs were somewhat higher than for the other methods, and hair snares were the least costly. In addition to achieving relatively high levels of detection, detection dogs required only one site visit for survey completion (i.e., 1-d latency-to-first detection). This point is not trivial, especially when long driving distances, difficult walk-in conditions, or complex land ownership patterns make coordinating and gaining access to sites logistically challenging.

We used a carpet pad hair snare design that was originally developed for felids (McKelvey et al. 1999) but failed to detect bobcats at any of our sites. Other Northeast studies employing hair snares for felids have also been largely unsuccessful. For example, hair snares failed to detect Canada lynx in New York's Adirondack Park at a reintroduction site where they were known to occur (J. Weaver, personal communication). Further, surveys for Canada lynx across National Forests in Vermont failed to detect lynx or bobcat, despite the fact that bobcats were thought to be common in many of the survey areas (M. B. Burbank, USDA Forest Service, personal communication). Predictably (given the design), we also failed to detect fishers with hair snares, and hair snares were relatively ineffective (compared with cameras and detection dogs) at detecting black bears. Other hair snare mechanisms designed specifically for ursids (Triant et al. 2004) and mustelids (Zielinski et al. 2006) may have increased detection rates had they been used at our sites.

Our protocols for both remote cameras and hair snares should be considered minimalist, as most studies employing these devices revisit and rebait survey stations every 2 days–1 week and deploy cameras at higher densities (Zielinski and Kucera 1995, Carroll et al. 1999, Moruzzi et al. 2002, Campbell 2004, Gompper et al. 2006). The benefits associated with more frequent revisits are 2-fold: camera malfunctions can be corrected earlier in the survey, and frequent rebaiting may increase detectability. Increasing camera density may have also increased detectability in our study by effectively enlarging the actual area surveyed and by preventing the loss of data from a given site if a single camera failed. Both increasing the number of revisits and increasing camera density, however, would have substantially increased project cost.

In contrast to station-based survey methods such as remote cameras, hair snares, and track plates, detection dogs require no attractants or baiting of target animals. This characteristic may reduce potential biases if different segments of a population (e.g., M and F) are variably drawn to attractants, and allows for a more accurate estimation of spatially explicit parameters such as habitat use or home range size. Further, nonreward-based detection methods eliminate the supplemental feeding of wildlife and minimize the chance of attracting animals to potentially hazardous locations (e.g., road edges, forest openings).

It is important to emphasize that detection dogs located scats deposited by target species but did not detect actual animals. Given that scats persist in the environment for days, weeks, or even months, the detection of a scat does not necessarily mean that the area is currently occupied by the target species but only that the site was used by the species in the recent past (Long et al. 2007). Although scat persistence advantageously extends the time period over which a species can be detected, care should be taken to account for potential temporal mismatches between an animal's presence and the presence of its scat. The ability of dogs to detect scat long after deposition may confound comparisons between dogs and other methods, such as remote cameras, which detect species presence at the actual time of the survey. At sites where we conducted both dog surveys and valid remote camera surveys, however, only 2.6% (1/39) of black bear detections by dogs were based solely on scats estimated to be $\geq$1 month of age (see Long et al. 2007 for a description of

Table 2. Estimates of total and per site costs for conducting 2 hypothetical 60-site surveys using either a leased detection dog, a detection dog purchased at the outset of the project, remote cameras, or hair snares. Costs are in United States dollars and calculated based on data collected in Vermont and New York during May–August 2003 and 2004.

			Survey 1 cost		Survey 2 cost		Both surveys	
Method	**Category**	**Item**	**Total**	**Per site**	**Total**	**Per site**	**Total**	**Per site**
Leased detection dog	Labor[a]	Handler training	1,200	20.00	400	6.67	1,600	13.33
	Labor	Orienteer training	400	6.67			400	3.33
	Labor	Site visits	4,800	80.00	4,800	80	9,600	80.00
	Labor	Site revisits						
	Transport	Field vehicle fuel & repairs	600	10.00	600	10.00	1,200	10.00
	Transport	Airfare[b]	700	11.67	700	11.67	1,400	11.67
	Dog related	Dog leasing	4,500	75.00	4,500	75.00	9,000	75.00
	Dog related	Handler training	4,500	75.00	1,500	25.00	6,000	50.00
	Dog related	Dog supplies & vet costs	960	16.00	960	16.00	1,920	16.00
	Miscellaneous	Miscellaneous	300	5.00	300	5.00	600	5.00
	DNA	DNA analyses[c]	3,098	51.64	3,098	51.64	6,196	51.64
Leased detection dog totals			21,058	351	16,858	281	37,916	316
Purchased detection dog	Labor[a]	Handler training	1,200	20.00			1,200	10.00
	Labor	Orienteer training	400	6.67			400	3.33
	Labor	Site visits	4,800	80.00	4,800	80.00	9,600	80.00
	Labor	Site revisits						
	Transport	Field vehicle fuel & repairs	600	10.00	600	10.00	1,200	10.00
	Transport	Airfare[d]	350	5.83			350	2.92
	Dog related	Dog purchase	5,000	83.33			5,000	41.67
	Dog related	Handler training	4,500	75.00			4,500	37.50
	Dog related	Dog supplies and vet costs	960	16.00	668	11.13	1,628	5.17
	Dog related	Off-season dog supplies[e]					316	2.63
	Miscellaneous	Miscellaneous	300	5.00	200	3.33	500	4.17
	DNA	DNA analyses[c]	3,098	51.64	3,098	51.64	6,196	51.64
Purchased detection dog totals			21,208	353	9,366	156	30,890	257
Remote camera	Labor[a]	Personnel training	160	2.67			160	1.33
	Labor	Site visits	3,600	60.00	3,600	60.00	7,200	60.00
	Labor	Site revisits	3,200	53.33	3,200	53.33	6,400	53.33
	Transport	Field vehicle fuel & repairs	900	15.00	900	15.00	1,800	15.00
	Camera related	Cameras[f]	8,000	133.33			8,000	66.67
	Camera related	Film & processing	375	6.25	375	6.25	750	6.25
	Camera related	Batteries	180	3.00	180	3.00	360	3.00
	Attractants	Bait & scent lures	240	4.00	240	4.00	480	4.00
	Miscellaneous	Miscellaneous	240	4.00	240	4.00	480	4.00
Remote camera totals			16,865	282	8,735	146	25,630	214
Hair snare	Labor[a]	Personnel training	160	2.67			160	1.33
	Labor	Site visits	2,400	40.00	2,400	40.00	4,800	40.00
	Labor	Site revisits	2,400	40.00	2,400	40.00	4,800	40.00
	Transport	Field vehicle fuel & repairs	900	15.00	900	15.00	1,800	15.00
	Snare related	Materials	40	0.67	40	0.67	80	0.67
	Attractants	Scent lures	165	2.75	165	2.75	330	2.75
	Miscellaneous	Miscellaneous	100	1.67	100	1.67	200	1.67
	DNA	DNA analyses[c]	3,098	51.64	3,098	51.64	6,196	51.64
Hair snare totals			9,263	154	8,103	152	18,366	153

[a] We calculated all labor costs using a base rate of $10/hr.
[b] Includes airfare for handler and cargo fee for return of detection dog.
[c] Estimate based on 2 samples/site.
[d] Includes airfare for handlers.
[e] Estimate based on supplies required for portion of the yr during which surveys are not being conducted.
[f] Estimate based on 20 new cameras at $400 each.

aging scats). Thus, most black bear scat detections reflected bear use during the same general period as that surveyed by cameras and hair snares. Unfortunately, we were unable to assign ages to fisher and bobcat scats based on morphological characteristics, but because these species typically range less widely than black bears and tend to be strongly territorial, scat presence suggested that individuals were likely still using the survey site.

Spatial issues are also important to consider when comparing detection methods, as methods should ideally sample comparable areas. Detection dog surveys constituted physical searches of a relatively large area, whereas remote cameras and hair snare surveys were conducted from a single point and relied on scent lure and bait to attract target species to the detection site. Without additional information (e.g., Global Positioning System collar locations from target individuals in the area), it is difficult to estimate the area actually surveyed by attraction-based methods. We used relatively subtle attractants (e.g., visual reflector, chicken) in combination with a long-call lure (e.g., a skunk-based scent) to ensure sampling of target individuals whose home-range included part or all of the survey area. Although no studies have attempted to estimate the call range of such lures, our 14-day sampling duration was intended to provide ample time for animals to encounter a detection device within their home-range.

The estimated cost of hypothetical surveys differed by method, with those using a leased detection dog requiring approximately 1.5 times the amount of funding necessary for camera-based surveys and twice the funding necessary for hair snare surveys. It is important, however, that the relative effectiveness of each method be taken into account when comparing costs. For many applications (e.g., surveys for endangered species), researchers require a high probability of detecting the target species. Further, low probabilities of detection decrease the accuracy and precision of occupancy estimates (MacKenzie et al. 2002). If the effort necessary to achieve a relatively high probability of detection is accounted for, detection dogs are clearly the more cost effective method.

The cost of a detection dog-based survey program may be reduced by purchasing ≥ 1 trained detection dog to be employed across multiple field seasons. Such an approach would require significant planning and commitment in terms of providing the dog with appropriate long-term care and housing. Beyond leasing or purchasing detection dogs, a third option—that of hiring experienced dog-handler teams on a per-day or per-project basis—is now available to researchers. Researchers interested in using scat detection dogs should consult with an established detection dog organization for current pricing (e.g., Packleader Dog Training, Gig Harbor, WA; Working Dogs for Conservation Foundation, Three Forks, MT; University of Washington Center for Conservation Biology, Seattle, WA).

DNA analysis represented much of the cost per site for detection dog and hair snare surveys. This expense could be substantially reduced if target species yield unambiguous scats or hair (e.g., black bears in our study), or if close collaboration with a DNA lab is feasible. Further, for monitoring efforts that are to be repeated often, overall per site costs associated with purchasing detection dogs or cameras would effectively continue to decrease throughout the respective lifespan of the dog or camera.

Despite lower per visit probabilities of detecting target species with remote cameras and hair snares than with detection dogs, we assume that the benefits of remote cameras (e.g., instant positive identification of target species, long deployment potential, measure of current use, multi-species monitoring, public relations value of photos) and hair snares (e.g., long deployment potential, measure of current use, low material costs, minimal training requirements) will continue to make these techniques attractive to researchers. Advances in camera reliability and digital technology should further increase the effectiveness of remote cameras. Similarly, ongoing advances in the design of species-specific hair snares (e.g., Belant 2003, Bremner-Harrison et al. 2006, Zielinski et al. 2006) will maximize the benefits of hair snares for noninvasive sampling.

MANAGEMENT IMPLICATIONS

We found scat detection dogs to be substantially more effective and efficient (i.e., cost/detection) than remote cameras and hair snares for documenting the presence of black bears, fishers, and bobcats in Vermont. We suggest that researchers seeking to detect carnivores and collect scat samples consider the use of detection dogs, especially when high detectability and minimal bias are priorities. It is essential that more studies are conducted to test and quantify the ability of detection dogs to survey a diversity of species under a variety of field conditions, and to compare the effectiveness of dogs with other survey methods. Due to the considerable logistical considerations associated with effectively planning and implementing a detection dog-based project, we strongly encourage researchers to consult professional trainers who possess relevant experience prior to project initiation. Survey objectives, availability of personnel, climate, topography, and other factors will help to determine whether detection dogs are the most appropriate method for a particular survey or study (Long et al. 2007).

ACKNOWLEDGMENTS

We thank B. Davenport, D. MacKenzie, D. Paetkau, A. Royle, S. Wasser, S. Weigley, J. Weldon, our field personnel, and our scat detection dogs for their contributions to this project. The Vermont Cooperative Fish and Wildlife Research Unit is jointly sponsored by the United States Geological Survey, the Vermont Fish and Wildlife Department, the University of Vermont, and the Wildlife Management Institute. Funding for this project was provided by the Vermont Department of Fish and Wildlife, the Northeastern States' Research Cooperative, the Jon C. and Katherine L. Harvey Charitable Foundation, the Southern Lake Champlain Valley Office of the Nature Conservancy, Sweet Water Trust, the USDA Forest Service, and the United States Geological Survey. Finally, we thank W. Pitt and 2 anonymous reviewers for their valuable comments on this manuscript. Mention of services used in this research does not confer endorsement by the United States federal government.

LITERATURE CITED

Belant, J. L. 2003. A hairsnare for forest carnivores. Wildlife Society Bulletin 31:482–485.

Bremner-Harrison, S., S. W. R. Harrison, B. L. Cypher, J. D. Murdock, and J. Maldonado. 2006. Development of a single-sampling noninvasive hair snare. Wildlife Society Bulletin 34:456–461.

Campbell, L. A. 2004. Distribution and habitat associations of mammalian carnivores. Dissertation, University of California, Davis, USA.

Carroll, C., W. J. Zielinski, and R. F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath region, U.S.A. Conservation Biology 13:1344–1359.

Gompper, M. E., R. W. Kays, J. C. Ray, S. D. LaPoint, D. A. Bogan, and

R. J. Cryan. 2006. A comparison of noninvasive techniques to survey carnivore communities in Northeastern North America. Wildlife Society Bulletin 34:1142–1151.

Harrison, R. L. 2006. A comparison of survey methods for detecting bobcats. Wildlife Society Bulletin 34:548–552.

Heilbrun, R. D., N. J. Silvey, M. E. Tewes, and M. J. Peterson. 2003. Using automatically triggered cameras to individually identify bobcats. Wildlife Society Bulletin 31:748–755.

Long, R. A., T. M. Donovan, P. MacKay, W. J. Zielinski, and J. S. Buzas. 2007. Effectiveness of scat detection dogs for detecting forest carnivores. Journal of Wildlife Management 71:2007–2017.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

McDaniel, G. W., K. McKelvey, J. R. Squires, and L. F. Ruggiero. 2000. Efficacy of lures and hair snares to detect lynx. Wildlife Society Bulletin 28:119–123.

McKelvey, K. S., J. J. Claar, G. W. McDaniel, and G. Hanvey. 1999. National lynx detection protocol. Rocky Mountain Research Station. Missoula, Montana, USA

Moruzzi, T. L., T. K. Fuller, R. M. DeGraaf, R. T. Brooks, and W. Li. 2002. Assessing remotely triggered cameras for surveying carnivore distribution. Wildlife Society Bulletin 30:380–386.

Sequin, E. S., M. M. Jaeger, P. F. Brussard, and R. H. Barrett. 2003. Wariness of coyotes to camera traps relative to social status and territory boundaries. Canadian Journal of Zoology 81:2015–2025.

Smith, D. A., K. Ralls, B. L. Cypher, and J. E. Maldonado. 2005. Assessment of scat-detection dog surveys to determine kit fox distribution. Wildlife Society Bulletin 33:897–904.

Smith, D. A., K. Ralls, B. Davenport, B. Adams, and J. E. Maldonado. 2001. Canine assistants for conservationists. Science 291:435.

Smith, D. A., K. Ralls, A. Hurt, B. Adams, M. Parker, B. Davenport, M. C. Smith, and J. E. Maldonado. 2003. Detection and accuracy rates of dogs trained to find scats of San Joaquin kit foxes (*Vulpes macrotis mutica*). Animal Conservation 6:339–346.

Triant, D. A., R. M. Pace, and M. Stine. 2004. Abundance, genetic diversity and conservation of Louisiana black bears (*Ursus americanus luteolus*) as detected through noninvasive sampling. Conservation Genetics 5:647–659.

Wasser, S. K., B. Davenport, E. R. Ramage, K. Hunt, M. Parker, C. Clarke, and G. Stenhouse. 2004. Scat detection dogs in wildlife research and management: application to grizzly and black bears in the Yellowhead Ecosystem, Alberta, Canada. Canadian Journal of Zoology 82:475–492.

Weaver, J. L., P. Wood, D. Paetkan, and L. L. Laack. 2005. Use of scented hair snares to detect ocelots. Wildlife Society Bulletin 33:1384–1391.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:120–138.

Zielinski, W. J., and T. E. Kucera. 1995. American marten, fisher, lynx, and wolverine: survey methods for their detection. USDA Forest Service Pacific Southwest Research Station General Technical Report PSW-GTR-157, Albany, California, USA.

Zielinski, W. J., F. V. Schlexer, K. L. Pilgrim, and M. K. Schwartz. 2006. The efficacy of wire and glue hair snares in identifying mesocarnivores. Wildlife Society Bulletin 34:1152–1161.

Zielinski, W. J., R. L. Truex, F. V. Schlexer, L. A. Campbell, and C. Carroll. 2005. Historical and contemporary distributions of carnivores in forests of the Sierra Nevada, California, USA. Journal of Biogeography 32:1385–1407.

Associate Editor: Pitt.