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# A Comparison of Noninvasive Techniques to Survey Carnivore Communities in Northeastern North America

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## Abstract

*Carnivores are difficult to survey due, in large part, to their relative rarity across the landscape and wariness toward humans. Several noninvasive methods may aid in overcoming these difficulties, but there has been little discussion of the relative merits and biases of these techniques. We assess the value of 5 noninvasive techniques based on results from 2 multiyear studies of carnivores (including members of Carnivora and Didelphidae) in New York forests. Two metrics were particularly valuable in assessing the species-specific value of any particular survey technique: latency to initial detection (LTD) and probability of detection (POD). We found differences in the value of techniques in detecting different species. For midsized species (raccoon [*Procyon lotor*], fisher [*Martes pennanti*], opossum [*Didelphis virginiana*], and domestic cat [*Felis catus*]), camera traps and track-plates were approximately equivalent in detection efficiency, but the potential for wariness toward the survey apparatus resulted in higher LTD for track-plates than for cameras. On the other hand, track-plates detected small carnivores (marten [*M. americana*] and weasels [*Mustela* spp.]) more often than cameras and had higher PODs for small and midsized species than did cameras. Cameras were efficient mechanisms for surveying bears (*Ursus americanus*; low LTD, high POD) but functioned poorly for discerning presence of coyotes (*Canis latrans*; high LTD, low POD). Scat surveys and snowtracking were the best methods for coyotes, which avoided camera traps and artificial tracking surfaces. Our analysis of fecal DNA revealed that trail-based fecal surveys were inefficient at detecting species other than coyotes, with the possible exception of red foxes (*Vulpes vulpes*). Genetic analyses of feces and snowtracking revealed the presence of foxes at sites where other techniques failed to discern these species, suggesting that cameras and track-plates are inefficient for surveying small canids in this region. The LTD of coyotes by camera traps was not correlated with their abundance as indexed by scat counts, but for other species this metric may offer an opportunity to assess relative abundance across sites. Snowtracking surveys were particularly robust (high POD) for detecting species active in winter and may be more effective than both cameras and track-plates where conditions are suitable. We recommend that survey efforts targeting multiple members of the carnivore community use multiple independent techniques and incorporate mechanisms to truth their relative value.* (WILDLIFE SOCIETY BULLETIN 34(4):1142–1151; 2006)

## Key words

*camera traps, carnivores, fecal DNA, latency to detection, New York, noninvasive survey, probability of detection, snowtracking, track-plates.*

Species in the mammalian order Carnivora receive a great deal of conservation attention, much of which is due to a charismatic and conflict-ridden image that draws attention from diverse segments of society, as well as their importance as furbearers (Gittleman et al. 2001, Ray et al. 2005). But there also is an interest in these species because of their potential to fundamentally influence communities and ecosystems in ways that are disproportional to their biomass in the system (Estes et al. 1998, Post et al. 1999, Terborgh et al. 1999, Ray et al. 2005). It is increasingly clear that even midsized and small predators may be fundamental drivers of ecosystem processes despite their relative rarity across landscapes (Jędrzejewska and Jędrzejewski 1998, Korpimaki and Norrdahl 1998, Gittleman and Gompper 2005). As a result an increasing number of studies are attempting to assess presence or absence, relative abundance, and interaction of carnivore species across the globe.

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Techniques to study the ecology of carnivores typically are invasive; that is, they require capture and handling of individual animals. This intensive work usually is impractical for studies addressing questions over larger geographic scales and also may be inappropriate because of local norms and regulations, costs and logistics, low potential to capture the target species, or risk to the target animal. Yet, because carnivores range over large areas and frequently interact with one another (Palomares and Caro 1999), biologists and wildlife managers are increasingly recognizing the need for large-scale studies of entire carnivore communities. Thus, there has been a push to develop noninvasive survey techniques that can be deployed over large areas and detect multiple species (e.g., Zielinski and Kucera 1995). Five of the most commonly used of these noninvasive techniques are camera traps, covered track-plates, scent stations, snowtracking, and scat surveys. The latter technique is increasingly paired with DNA-based analyses to enhance accuracy.

While there have been several reviews of carnivore survey techniques (e.g., Raphael 1994, Zielinski and Kucera 1995, Gese 2001, 2004, Wilson and Delahay 2001), and some techniques have been compared and critiqued on a case-by-case basis (e.g., Foresman and Pearson 1998, Harrison et al. 2002), there have been few attempts to compare the relative merits of these techniques across an entire carnivore guild. Quantifying technique efficiencies and biases is critical for making decisions about which survey method to employ as well as proper study design. Given that efficacy probably varies across species and habitat, it is important that a series of comparisons be made across the carnivore guild within a single region.

In addition, there have been occasional efforts to use noninvasively collected data to assess relative population abundance (e.g., Beltrán et al. 1991, Cavallini 1994, Carbone et al. 2001, 2002, Dijak and Thompson 2000). For some techniques such as snowtracking or DNA-enhanced scat surveys, use of sampling designs that allow estimates of relative abundance (Raphael 1994, Lindén et al. 1996, Becker et al. 1998, Kohn et al. 1999, Prugh et al. 2005) may provide a distinct advantage of the technique relative to other noninvasive methods. For most noninvasive techniques, however, the utility of the noninvasively collected data for quantifying and monitoring population size is unclear because animals cannot be individually identified and because detections of signs or tracks may be imperfect (Conner et al. 1983, Andelt and Andelt 1984, Nottingham et al. 1989, Smith et al. 1994, Sargeant et al. 1998, Jennelle et al. 2002, Hamm et al. 2003, Livingston et al. 2005). Thus, there remain important gaps in our knowledge of the value of noninvasive techniques that must be addressed if these methodologies are to gain widespread acceptance.

We used data from our multitechnique studies of the carnivore guilds in 2 regions of northeastern North America to quantify the strengths and limitations of noninvasive survey methods commonly used by carnivore ecologists. Our specific objectives were to 1) make species-specific recommendations, 2) explore how these 5 techniques can be used to go beyond detection to relative abundance measures, and 3) bring forward study-design considerations when deploying noninvasive survey techniques.

## Study Area

Our technique comparisons took place in 2 regions of New York State. The individual studies that occurred at these sites were not a priori designed to be comparative with one another; study sites involved different scales, research agendas, techniques, and study species. We targeted terrestrial carnivores but also include results from the common opossum (*Didelphis virginiana*) because it was frequently attracted to our baits and its foraging ecology may be similar to some species of Carnivora.

### Adirondack State Park, New York

Adirondack State Park (ADK; approx. 25,000 km$^2$) in northern New York is the largest park in the contiguous United States (Jenkins 2004). Our focus in ADK was to understand the interactions of habitat preferences and intraguild relationships in structuring the carnivore community (J. C. Ray et al., Wildlife Conservation Society, unpublished data). Fieldwork occurred at 54 sites spread throughout the park and surrounding region, in a variety of forested and anthropogenic habitats. At each site we marked a 5-km transect along hiking trails and unpaved roads. We surveyed carnivore presence along each transect using 3 noninvasive techniques: baited camera traps, track-plates, and scat surveys supplemented with fecal-DNA studies.

### Albany Pine Bush Preserve, New York

The Albany Pine Bush Preserve (APB) in east-central New York is a small protected area surrounded and bisected by suburban development (Rittner 1976, Barnes 2003). Research focused mainly on the ecology of coyote (*Canis latrans*), foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), and feral cats (*Felis catus*) in fragmented ecosystems and the main noninvasive techniques were camera trapping, snowtracking, and scent stations (Kays and DeWan 2004). Field sampling was concentrated within 37.6 km$^2$ of mixed deciduous–coniferous forests in a broader 60-km$^2$ area that also included suburban and commercial development. At larger scales, this area was flanked by urban development to the east and north and a mix of suburban development and rural areas to the west and south.

## Methods

All photography involved the use of motion-sensitive infrared triggered still cameras, with primary reliance on Camtracker II (Camtrak South Inc., Watkinsville, Georgia) and the use of attractants (baits or scented lures). We wired bait (2–5 kg of chicken, deer, or beaver) to trees at approximately 2-m height, 5–50 m off the trails and placed a skunk-scented lure (Gusto®, Caven's, Minnesota Trapline Products, Pennock, Minnesota) at the site. We mounted cameras ($n = 3$ per transect) at $<0.5$-m height on trees approximately 5–10 m from the bait using elastic bungee cords and cable locks, and left them in place for 28–32 days at each ADK locality (mean number of trap nights per transect in ADK = 88) and for 1 day at each APB scent station (see below). We set all cameras to record date and time when triggered. We visited ADK cameras approximately every 10 days to check film and replenish bait. We moved APB cameras daily.

We placed track-plates ($n = 6$ per site in ADK) in the forest, approximately 25 m off trails at 500-m intervals and baited them with one chicken leg and a skunk-scented lure (Gusto). Design of the track-plates was similar to that of Zielinski and Kucera (1995) but differed in that the plates were placed within a corrugated plastic (Coroplast™, Coroplast Inc., Dallas, Texas) housing rather than a plywood box to protect against weathering (Fig. 1). This product is lightweight, inexpensive, flexible, more durable, and in many cases less expensive than similar-sized wood products. We applied soot to aluminum plates with a portable kerosene lantern made from a paint can. We

***Figure 1.*** Enclosed track-plate design. Soot-covered aluminum track-plate is placed within corrugated plastic housing. This housing is light-weight and inexpensive and can be easily folded for transport. Bottom right displays a positive survey result from 2000 in which an Adirondack fisher has walked across the soot and left tracks on contact paper.

attached contact paper to the baited end of the aluminum plate to collect footprints. We checked and rebaited track-plates every 2–3 days and left them on site for 11–15 days per locality (mean number of trap nights per transect = 75).

In APB we directly compared the abilities of cameras and tracking plots to detect carnivores attracted to a scent tablet. From June to August 2001, we surveyed 22 forested sites using 108 plots. All study sites had coniferous–deciduous forest cover and were imbedded in a suburban (not commercial or industrial) landscape. Twenty-one sites had 5 scent stations spaced every 58 m around a circle radiating 50 m from a common center point; one site had only 3 scent stations due to the small size of the forest fragment. We opened each scent station for one night. A scent station consisted of a fatty acid scent tablet (Andelt and Woolley 1996) placed in the center of a 1-m-radius circle of raked sandy soil to record footprints of visiting animals. This radius is larger than most studies and allowed assessment of how far from the center the tracks were as a measure of how important track substrate dimension might be. Because the soil is naturally sandy in this area, no artificial substrates were necessary. Each scent station also was monitored with a camera trap set 10 cm aboveground, 2–5 m from the scent tablet. If rain obscured tracks, the site was resampled at a later date. We sampled large forest fragments (>40 ha) at both their center (>100 m from forest edge) and edge (<100 m from forest edge).

We carried out scat surveys solely in ADK with a primary focus on identifying the presence and relative abundance of coyotes, although we collected all suspected nonbear carnivore scats. We cleared each 5-km transect of scats and then walked each transect once monthly for 3 consecutive summer months. We collected all scats in paper bags and stored them immediately at −20°C. We extracted DNA from scats collected in a subset of 35 sites that had at least 5 suspected coyote scats with Qiagen QIAmp DNA Stool Mini kit (QIAGEN Inc., Valencia, California). To identify species we first used the MDO mitochondrial DNA primer to identify scats of coyotes (J. W. Maldonado, Smithsonian Institution, unpublished data). We performed genotyping on an ABI 3100 Genetic Analyzer (GE Healthcare Technologies, Waukesha, Wisconsin) at the New York State Health Department. Samples identified as noncoyote were then sequenced using the same primer pair on an ABI Prism 3700 DNA Analyzer (GE Healthcare Technologies). These unknown sequences were aligned to those from candidate species obtained from GenBank (http://www.ncbi.nih.gov/Genbank/) or sequenced from the New York State Museum tissue collection. In total we tested 472 fecal samples and obtained sufficient high-quality DNA to confirm species of origin for 377 (79.9%).

In APB we used snowtracking to survey presence or absence, and relative activity level for medium and large mammals by surveying a 1-ha plot within 21 independent study sites. A team of 2–3 biologists trained in snowtracking thoroughly surveyed each plot the morning after one full night of fresh snowfall. Surveys were conducted a total of 4 times over 2 winters.

A difficulty in comparing different techniques is choosing the appropriate metric. Measures such as simple visitation rates are a starting point but can be difficult to interpret if survey efforts vary by technique or if the independence of visitations is unknown. Two relatively novel metrics overcome some of these difficulties and can, therefore, be used to compare technique efficacy: latency to initial detection (LTD; Foresman and Pearson 1998) and probability of detection (POD; MacKenzie et al. 2002). The former was defined as the time (in days) until initial detection of a species at a survey site and was calculated only for camera (from photo stamps) and track-plate data (at checking intervals; because track-plates in ADK were not checked daily, estimates of LTD may be slightly biased upwards). The latter measure (POD) was the likelihood that a species was detected with a given technique when present at a survey site. Within a population, more efficient survey techniques should result in a lower LTD and higher POD.

We used the program PRESENCE (MacKenzie et al. 2002) to calculate POD per transect for cameras (approx. 30 daily intervals), track-plates (approx. 43-day intervals), and scat collection (3 transect visits) in ADK, and for snowtracking (4 site visits) in the APB. This method uses

*Table 1.* Percentage of Adirondack sites ($n = 54$) at which each species was detected by any technique ($n = 8,796$ survey nights), by cameras ($n = 4,728$), and by track-plates ($n = 4,068$) during 2000–2002. The columns showing the species missed by a technique are the percentage of sites where a species was detected with one technique but not the other.

| Species | Detected with any technique | Detected with cameras | Detected with track-plates | Missed by cameras | Missed by track-plates |
|---|---|---|---|---|---|
| Coyote | na | 40.7 | na | na | na |
| Black bear | na | 61.1 | na | na | na |
| Opossum | 9.3 | 5.6 | 9.3 | 25.0 | 0 |
| Weasel | 16.7 | 3.7 | 13.0 | 100 | 100 |
| Raccoon | 50.0 | 31.5 | 44.4 | 54.2 | 35.3 |
| Marten | 18.5 | 5.6 | 16.7 | 88.8 | 33.3 |
| Fisher | 61.1 | 55.6 | 33.3 | 27.8 | 56.7 |
| Gray fox | 1.9 | 1.9 | 0 | 0 | 100 |
| Red fox | 3.7 | 3.7 | 0 | 0 | 100 |

a maximum likelihood approach to estimate the probability that a species will be detected at least once when it is present at a site and assumes that the likelihood of detection does not change over the course of the survey effort (MacKenzie et al. 2002). We believe this assumption is valid for data collected in ADK, where cameras, track-plates, and scat surveys at each site were all run during the course of one summer. The APB snowtacking data was collected over 2 winters, so this assumption may be violated. However, given the relatively low variability in POD for snowtracking (see Results), we believe violations of this assumption may be of minor consequence for assessing the relative merits of the snowtracking compared to other survey techniques.

To ensure the visit of one animal to our cameras and track-plates did not reduce the chance for subsequent visits by other animals, we regularly rebaited, and for cameras used a substantial quantity (2–5 kg of bait plus a lure), which was secured under wire and unlikely to disappear from a site prior to the periodic checks. We only carried out estimates of POD at the site level (considered independent based on distance from one another being >5 km) where the species was known to exist from pooled camera, track-plate, and scat collection data sets. We converted the survey-length POD ($p_{\text{total survey}}$) into a per-check probability ($p_{\text{check}}$) using an equation derived from Campbell (2004): $p_{\text{check}} = 1 - (1 - p_{\text{total survey}})^n$, where $n$ is the conversion metric (1/number of survey intervals). Because we collected the snowtracking data one full night after a fresh snowfall, we consider this a daily probability. Although we collected scats from a site once a month, we do not know the time period over which scats accumulate or decay before our collection and, therefore, leave this as a per-survey probability. We used this same formula to extrapolate PODs for 12- or 30-day survey periods for cameras ($n = 12/30$) and track-plates ($n = 30/12$); this was only done when initial POD values had low variance (SE < 0.09).

Animal research followed guidelines established by the American Society of Mammalogists (American Society of Mammalogists Animal Care and Use Committee 1998). Our research protocol was approved by the Wildlife Conservation Society Animal Care and Use Committee and the New York State Department of Environmental Conservation permitting office (Permit No. LCP01-753).

## Results

### Carnivore Detection in the Adirondacks

Using baited cameras ($n = 4,728$ survey nights) and track-plates ($n = 4,068$ survey nights) we detected 10 species: coyote, black bear (*Ursus americanus*), weasels (ermine, *Mustela erminea*, and long-tailed, *M. frenata*), raccoon (*Procyon lotor*), marten (*Martes americana*), fisher (*Martes pennanti*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), and opossum. We could not always distinguish tracks of long-tailed weasels and ermine and so we combined results for these 2 species. We compared marten and weasel tracks with tracks from another track-plate survey (Loukmas et al. 2002, J. J. Loukmas, New York State Department of Environmental Conservation, unpublished data) to confirm that they were not mink (*M. vison*). We did not detect several species known to be in the region (e.g., bobcat [*Lynx rufus*], mink, otter [*Lontra canadensis*]) using these techniques. Lumping both techniques and excluding coyotes and bears (which could not be surveyed using enclosed track-plates due to large body size) resulted in detection rates across all 54 sites ranging from 2% (gray fox) to 61% (fisher; Table 1). Of the 5 most common species detected with both techniques, we recorded 4 at more trails with track-plates than cameras. Cameras tended to fail to detect smaller species more often, although none of these differences were significant within species or across all species detected by both methods.

Of the 377 successful fecal DNA genotypes from $n = 35$ sites, 88.9% were from coyote. At the 28 sites (80% of the 35 sites examined) where coyote presence was confirmed genetically, cameras detected coyotes at only 12 (42.9%), indicating that cameras are relatively inefficient in detecting presence of coyotes. Fecal DNA-based techniques also identified presence of red fox (6.6% of genotyped scats), marten (1.3%), mink (1.3%), fisher (0.8%), gray fox (0.5%), raccoon (0.3%), and domestic dog (*C. familiaris*; 0.3%). Our cameras and track-plates rarely or never detected 3 of these species: mink (scat found in 14.3% of 35 sites), gray fox (5.7%), and red fox (25.7%). There was no overlap between the 2 trails with photos of red fox and the 9 trails with red fox scat, suggesting neither technique was particularly efficient at detecting this species; the single gray fox photo was on the same trail where gray fox scat was found.

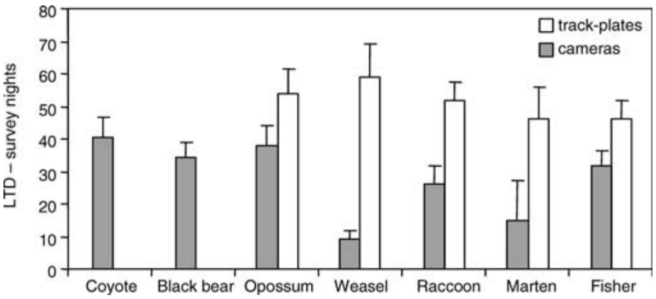


***Figure 2.*** Mean latency to initial detection (LTD) of a species across the Adirondacks during 2000–2002, subdivided by survey technique (cameras and track-plates). Values represent mean lag as measured in number of survey nights ± SE. Sites are only included if the species was eventually identified at the site by the technique of interest. Note that cameras ran for a greater period (approx. 4 weeks) than track-plates (approx. 2 weeks) at each site, but that fewer ($n = 3$ per site) cameras were used than track-plates ($n = 6$ per site). Coyotes and black bears were not detected at track-plates.

Absence of bobcat from the fecal DNA survey further supports their rarity or absence at our sites. We rarely detected marten (8.6%), fisher (8.6%), and raccoon (2.9%) from trail-collected scats.

The largest noncoyote scat was a 22-mm-diameter red fox sample. Of the 27 trails that had scats with both diameter measures and fecal DNA results (i.e., >5 large scats collected there), only one had no coyote scats >22 mm. Thus, 22 mm would be a conservative cutoff for identifying scats of eastern coyote; had we not employed fecal DNA techniques, this rule would have resulted in our misclassifying one noncoyote scat and missing the presence of coyotes on one trail. Using this >22-mm rule, 86.4% of our 54 sites had coyotes present.

Across all species for which both camera and track-plate data exist, the LTD for cameras was lower than for track-plates (Wilcoxon Signed Ranks Test: $n = 5$; $z = 2.023$; $P = 0.043$), but variance in LTD for cameras was relatively high (Fig. 2). Weasels and marten were most rapidly detected by cameras (approx. 9–15 survey nights) when present at a site, while coyotes (40.8 survey nights) had the greatest lag time. In contrast, across species, variance in track-plate LTD was low; mean LTD for 5 species ranged between 46 and 60 survey nights (7.7–10 days). There were no differences in LTD between the techniques for either fisher (paired $t = 1.842$, $\mathrm{df} = 9$, $P = 0.099$) or raccoon ($t = 0.1.383$, $\mathrm{df} = 9$, $P = 0.200$), the only species with sufficient sample sizes to allow statistical comparisons. The shape of the LTD histogram for ADK fishers and raccoons differed by techniques; for track-plates, but not cameras, there was an extended lag period prior to the detection of both species (Fig. 3). Even after correcting for the potential bias of the lower checking interval used for track-plates (2–3 days vs. 1 day for cameras), LTD for cameras was lower for each species than LTD for track-plates. Thus, when measuring detection success per survey night, cameras detected the 5 species sooner than track-plates.

We detected the 2 largest species, coyotes and bears, by cameras in sufficient numbers to allow the distribution of

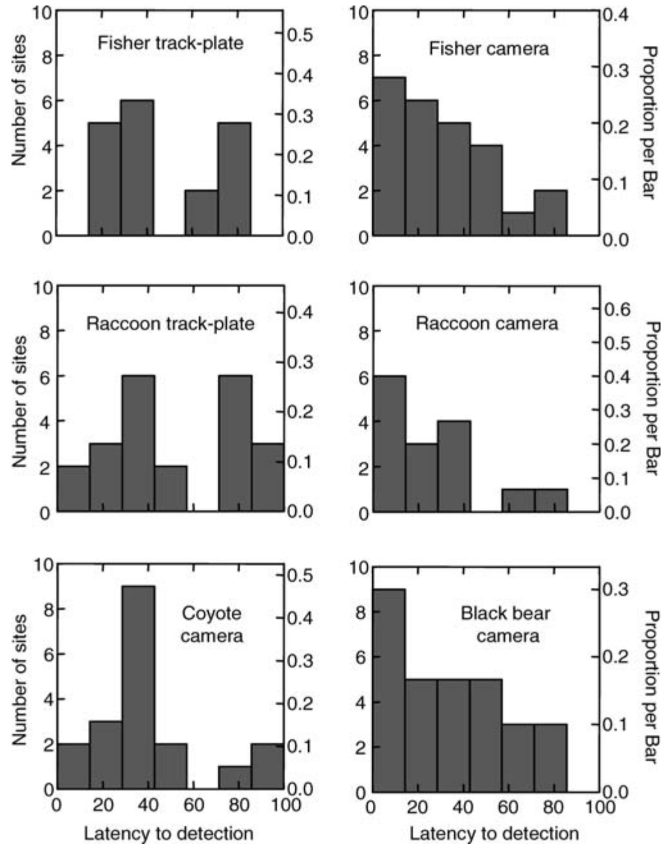


***Figure 3.*** Histograms of latency to detection for fishers and raccoons (cameras and track-plates) and for black bear and coyote (cameras only) based on data collected from the Adirondacks over 2000–2002. Latency to detection is given in number of survey nights.

their respective LTDs to be compared (Fig. 3). Mean LTDs were similar for both species (Fig. 2), but histogram shapes differed. As with fishers and raccoons at cameras (Fig. 3), we rapidly detected black bears when they were present. Coyotes, however, were unlikely to be detected by cameras in the first 30–45 survey nights (3 cameras for 10–15 days in this case). For coyotes, there also was no difference between number of putative coyote scats collected and whether cameras detected or failed to detect their presence ($t$-test with separate variance: $t = -0.104$, $\mathrm{df} = 38.1$, $P = 0.918$). Nor was there a significant relationship ($P = 0.684$) between number of putative coyote scats collected per day and the latency to detection by camera.

Two species (fisher, raccoon) had sufficient sample sizes to allow POD to be calculated for both cameras and track-plates. In these cases track-plates had a higher POD than camera traps (Fig. 4). The PODs for marten and weasels by track-plate methods were similar to those of fishers and raccoons; neither was detected frequently enough with cameras to calculate a POD, suggesting that track-plates are more efficient for these small species. Camera traps were relatively efficient at detecting bears, although with high levels of variance (Fig. 4). Similarly, variance in POD for coyotes also was high, but in contrast to bears, the mean POD value itself was the lowest of all species examined. Scat

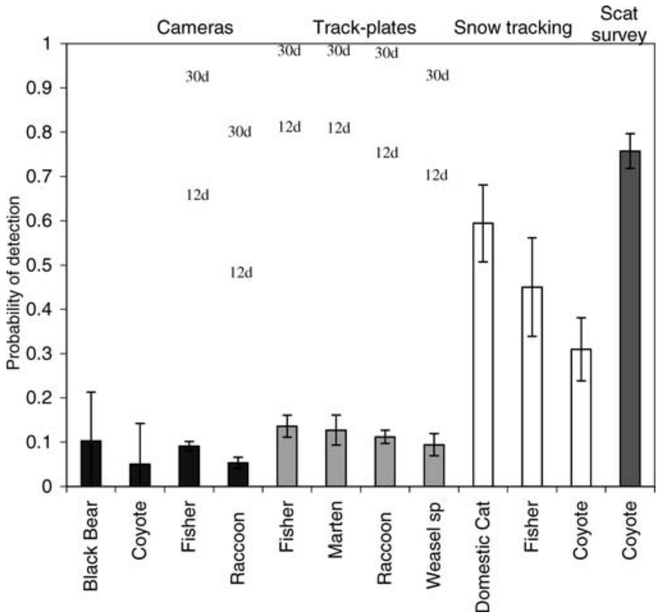


***Figure 4.*** Probability of detection (mean ± SE) per survey check for 4 survey methods. Effort per site was 3 cameras (Adirondack State Park [ADK]), 6 track-plates (ADK), 1 ha of snowtracking (Albany Pine Bush Preserve), and 5 km of trail-based scat survey (ADK). Extrapolated probabilities are indicated for 12-day (12d) and 30-day (30d) sample periods (only calculated for measures with low variance in the original measure).

surveys were much more efficient at detecting coyotes (Fig. 4). The POD calculated on a per survey night basis was extrapolated into 12- or 30-day survey periods; by this calculation our 12-day survey period for track-plates and 30-day survey period for cameras were appropriate (Fig. 4). Extending track-plates to 30 days would boost detection probabilities by an average of 20.1 across the 4 target species.

### Carnivore Detection in the Albany Pine Bush Preserve

We detected 9 species, including opossums, domestic cats (*Felis catus*), and domestic dogs, in the APB using snowtracking, cameras, or scent stations (Table 2). Despite the differences in survey efforts (cameras and scent stations recorded 1 night of activity, while snowtracking data represents data from 4 visits per site), several patterns emerged. For coyote, fisher, and gray foxes, snowtracking was more effective, with a larger proportion of sites identified as hosting the species (although this was only significant for coyotes, Fisher exact test $P = 0.009$; df $= 1$). These trends persisted even when we used the average proportion of sites with detections per snowfall instead of the combined results of 4 visitations. As expected, we only detected raccoons and skunks during summer due to reduced winter activity. For the remaining species, no technique stood out as particularly more efficient (Table 2).

In the experimental plots that simultaneously included both cameras and tracking media surrounding a scent tablet, cameras were more efficient at detecting carnivores; tracks were missing in 17.0% of carnivore detection events ($n = 53$), while photos were missed in only 1.9% of detections.

***Table 2.*** Percentage of Albany Pine Bush Preserve sites ($n = 20$) at which each species was detected by winter snowtracking (1-ha plots visited once after each of 4 snowfalls; value in parentheses = mean/snowfall event), summer camera traps (5 cameras run simultaneously over one day), and summer scent stations (each composed of 5 scent stations run simultaneously over one day). No techniques differed significantly except for coyotes (snowtracking vs. camera or scent stations; Fisher exact tests, $P = 0.009$).

| Species | Snowtracking | Camera | Scent stations | All techniques |
|---|---|---|---|---|
| Coyote | 55 (16.3) | 5 | 5 | 55 |
| Cat | 40 (23.8) | 50 | 50 | 65 |
| Dog | 40 (13.75) | 20 | 20 | 50 |
| Raccoon | 0 | 55 | 35 | 55 |
| Fisher | 25 (11.3) | 0 | 0 | 25 |
| Opossum | 15 (6.3) | 20 | 20 | 25 |
| Striped skunk | 0 | 10 | 10 | 25 |
| Red fox | 10 (2.5) | 10 | 5 | 20 |
| Gray fox | 20 (7.5) | 5 | 5 | 25 |

The bias toward detection by cameras rather than scent stations likely was due to animals coming close enough to the scent station to trigger the camera but not actually stepping on the sand. Even when we detected tracks, some animals did not walk near the center of the track station. A radius of only 50 cm would have detected 12.5% fewer raccoons ($n = 8$) and 4.5% fewer domestic cats ($n = 21$) and would have missed the single coyote track. Data from the 4 snowtracking events showed a high POD for coyotes, fishers, and domestic cats (Fig. 4).

## Discussion

Our data suggest that no single technique is ideal for surveying all species in the carnivore guild. The comparisons demonstrated that several commonly used techniques were inefficient for surveying particular species. For example, while baited cameras detected the most species, they performed poorly at identifying presence of coyotes compared with scat collection and were less efficient at detecting small-bodied species (e.g., weasel, marten) than track-plates. In addition, as revealed by the APB data and LTD comparisons, animals probably approach baited census units but are wary of stepping on tracking surfaces, causing them to be missed, especially during brief survey periods.

### Species-Specific Recommendations

The ADK and APB data suggest that coyotes should be surveyed by scat surveys, preferably backed by genetic confirmation of species of origin or by snowtracking. We surveyed black bear presence only in the ADK and only by camera, but the high rate of detection (61% of sites), short LTD, and the high POD suggests that this was an efficient method for detecting bears. We often detected raccoons, fishers, marten, weasels, domestic cats, and opossums by track-plates, scent stations, and cameras alike. In ADK cameras detected fishers, marten, raccoons, and weasels sooner than track-plates, although the 2 techniques gave similar results given sufficient sampling period. The POD for fishers and raccoons was higher for track-plates than cameras. Thus, rapid (<1 week) inventories of these species should use cameras to avoid the acclimation period that seems to precede the willingness of an individual to step into a track box. However, if more time can be invested, track-plates may be slightly more efficient for these species.

Our trail-based scat surveys proved efficient at detecting coyotes, with most (89%) feces collected originating from coyotes and a high POD with only 5 km of survey effort (Fig. 4). Genetic analyses may not be needed to survey coyotes in our region since a 22-mm minimum-size rule would only have reduced the number of sites from which coyotes were identified by one (4%) and would have only misidentified one noncoyote. Such an absolute cutoff, however, is probably only valid for northeastern coyotes, which are among the largest-bodied populations of the species (Gompper 2002); sites where coyotes are smaller or other larger predators (including bobcats where sufficient number exist) are present likely would have a greater probability of misidentifying scats. While genetic analyses did identify presence of foxes and mink that were not otherwise commonly detected, the high percentage of coyote scats indicates that trail-based surveys are inefficient for detecting noncanids in northeastern North America, although this conclusion has yet to be tested in areas where bobcats occur in reasonable numbers. For other species, a non–trail-based survey would necessitate alternative and more expensive survey protocols such as the use of scat-sniffing dogs (Smith et al. 2003). The value of trail-based surveys for canid scats also would have to be reevaluated if loss of scats (e.g., through effects of weather or traffic) from transects occurred at rates high enough to bias results (Sanchez et al. 2004, Godbois et al. 2005, Livingston et al. 2005).

Several species were poorly or never detected using any of the techniques. For instance, our survey techniques never detected bobcats, which are presumably rare in ADK, although the authors saw tracks of this species along the trail on 2 or 3 occasions during the study. Mink were detected in the ADK solely through the identification of scats collected along trails. Mink probably were missed by our track boxes because we did not target wetlands, as track-box surveys along rivers in northern New York have efficiently surveyed for mink (Loukmas et al. 2002).

### Abundance Measures

Most noninvasive methods are specifically designed to collect presence–absence data for each survey unit. Measures of relative or absolute abundance would be much more valuable but typically introduce more complexity through assumptions of independence or the increased data collection effort they require. Furthermore, indexes of abundance rarely are calibrated against true density estimates. Where they have been checked, raw counts of detections often have not measured up well against independent density measures (Conner et al. 1983, Nottingham et al. 1989, Smith et al. 1994, Sargeant et al. 1998), in part perhaps because a few individuals may be responsible for many detections. Naturally, the ability to reliably detect individuals opens up possibilities for applying mark–recapture techniques to derive density estimates. Beyond genetic identification of scats, the technique and species highlighted here do not make this possible (but see Herzog 2003, Herzog et al., New York State Museum, unpublished manuscript, regarding individual identification of fisher tracks). Royle and Nichols (2003) have shown that presence–absence data may be used to estimate abundance if collected repeatedly at the same sites with a study design set up to meet certain assumptions about independence of detections. Other metrics collected from noninvasive surveys also have potential to index abundance.

While several studies (Foresman and Pearson 1998, Moruzzi et al. 2002, Campbell 2004) have quantified LTD, we are not aware of any that have attempted to link this estimator to some measure of population density. If movement patterns are independent of local density (i.e., low-density animals do not move more), then the higher the density of a species in an area, the sooner an individual should encounter a survey location. However, several factors may restrict the value of LTD as a surrogate of local density. For instance, some species or some segment of a population may actively avoid visiting a survey station due to the novelty of the apparatus, its association with humans (Séquin et al. 2003), or the likelihood that visiting it could enhance the risk of deleterious interactions with members of other carnivore species (e.g., intra-guild predation or interspecific interference competition; Johnson et al. 1996, Cypher and Spencer 1998).

We only have one independent measure of relative abundance from our study that can be compared to LTD measures. While numbers of coyote feces per site correlates with the local coyote density (Knowlton 1984, Gese 2001, Kays et al., New York State Museum, unpublished data for ADK), there was no correlation between the abundance of coyote scats and LTD in ADK. Indeed, cameras regularly missed detecting coyotes at sites with large number of scats; coyote wariness towards cameras also can be seen in the LTD histogram (Fig. 3; see also Séquin et al. 2003). Coyotes are widely regarded as the most wary of the species we surveyed. The potential for LTD to relate to the density of other species should be evaluated by independent measures of abundance from additional field studies.

Counts of snowtracks also have the potential to serve as an index of local animal abundance (or activity). Large-scale surveys typically cover 3–10 km and count the tracks that cross the transect, with some control for independence (e.g., distance between track encounters or subdivided transect). While some of these indices appear to be biologically relevant (e.g., Lindén et al. 1996, Kurki et al. 1998, Pellikka et al. 2005), they are rarely calibrated against independent measures of animal density and typically have high coefficients of variation (reviewed by Becker et al. 2004). For small-scale surveys, such as our 1-ha plots, the sample unit is smaller than an individual's home range so that track counts would not be a measure of animal density but a measure of the local intensity of use (i.e., activity). In this case track independence is less of an issue, and measures of density of tracks per square meter could be used to compare local activity across sites.

### *Study Design Considerations*

The number of detection devices at a site, and their arrangement, is a question that rarely has been empirically addressed. Our decision to deploy 3 cameras and 6 track-plates along a linear transect resulted from a combination of standards used in other studies (Zielinski and Kucera 1995) and practical considerations. Yet it generally is assumed that more devices at a site increase the likelihood of detection or increase the number of detected animals. For some species, the possible enhanced detection potential of a camera-based survey unit relative to a track-based survey unit indicates an economic trade-off. Currently (mid-2005), the cost of camera traps starts at approximately US$200 per unit. One track-plate–based unit similar to that shown in Fig. 1 costs <5% of a single-camera unit. On the other hand, baited track-plates need to be checked every 2–3 days while baited cameras typically are checked every 7–10 days, given sufficient bait. Baiting track-plates with scent might reduce the labor involved but also may reduce visitation rates (Loukmas et al. 2002). Thus, while cameras may be more efficient at detecting presence of an animal in the initial census period, that efficiency could be offset by increasing the number of track-plate survey units with little increase in costs. This has yet to be rigorously tested.

A longer survey period increases the probability of detecting a species when present. Our extrapolations of POD values suggest that a track-plate survey of 12 days has a probability of detecting its target species (raccoons and mustelids) of approximately 0.7–0.8, and that extending this to 30 days would raise it to close to 1.0 (Fig. 4). Cameras required longer periods to reach these high probability levels, although this may relate to our survey design (using 6 track-plates but only 3 cameras per transect). In sum, our results concur with the general recommendation that surveys of approximately 2 weeks will detect most species present but that about 1 month is needed for exhaustive inventories (Moruzzi et al. 2002). Our LTD results further caution against brief (<1 week) surveys.

Whether the POD is higher on or off a trail has important bearing on placement of detection devices. For example, the rationale for placing cameras along trails is to enhance the likelihood of capture of species that habitually use such corridors for movement. This premise generally is confined to larger carnivores (Karanth and Nichols 1998, Henschel and Ray 2003, O'Brien et al. 2003), although canid scat collection along trails and roads is rooted in the same underlying principle (Kohn et al. 1999). Our comparisons of trail-based scat survey results with detection rates via other off-trail methods suggests differences in the tendency of species to use such trails as avenues for movement. For coyotes and foxes, even baited stations 25 m off trails underestimated presence of this species when compared with fecal evidence collected along trails. Perhaps cameras placed along trails might have obtained higher detection rates of these species. Unfortunately, trap placement along trails is only practical in remote areas with little or no human access. Otherwise, detection devices will be prone to theft or damage, or, in the case of cameras, high detection rates of humans themselves. For marten, fishers, weasels, and raccoons, on the other hand, the low occurrence of scats on trails indicated the opposite (probably compounded by the smaller size of their scats)—that these species do not disproportionately use trails as mechanisms for movements across a home range.

For most species active in winter, snowtracking probably has the highest probability of detecting presence of a species in an area in the shortest amount of time (Fig 4). However, practical considerations make this method difficult to use for standardized data collection. First, snow conditions may only be suitable in certain locales and, in some cases, for only a few days. Thus a tracking field crew must be ready to deploy on short notice. Second, the effects of weather and snow depth on animal movement may confound analyses of animal habitat use. Many animals move less when the snow is deep or temperatures are very low, making them less likely to be detected on a survey. Typically, snow and weather conditions are recorded on the survey day and incorporated as covariates in data analysis, allowing their effects to be factored out (Lindén et al. 1996, Gelok 2005). However, taking these into account by a priori sampling all sites on the same day completely removes weather as an influence, allowing habitats to be more robustly compared. Unless aircraft are used (e.g., Becker et al. 2004), this represents a trade-off between the scale of the area studied and the bias added by surveying in different weather conditions.

## Management Implications

Our findings indicate that cameras, track-plates, and snowtracking all have potential for community-wide surveys but that no single technique allows all members of a carnivore guild to be simultaneously surveyed. Cameras detect the most species but probably are biased against smaller species as well as wary larger species (e.g., coyote). Track-plates are only suitable for small and medium-sized species and also are biased against some wary species. Snowtracking overcomes biases against wary species but is only applicable to species active in the winter and requires acute attention to comparability when surveying multiple sites. We believe these guidelines should help researchers tailor their survey design to their target species in other parts of northeastern North America. Nonetheless, the use of noninvasive surveys is rapidly increasing, making it even more important to document and recognize the limitations and biases of these methods. Whenever possible, we recommend that researchers incorporate multiple independent techniques and that the value of these techniques be quantitatively contrasted.

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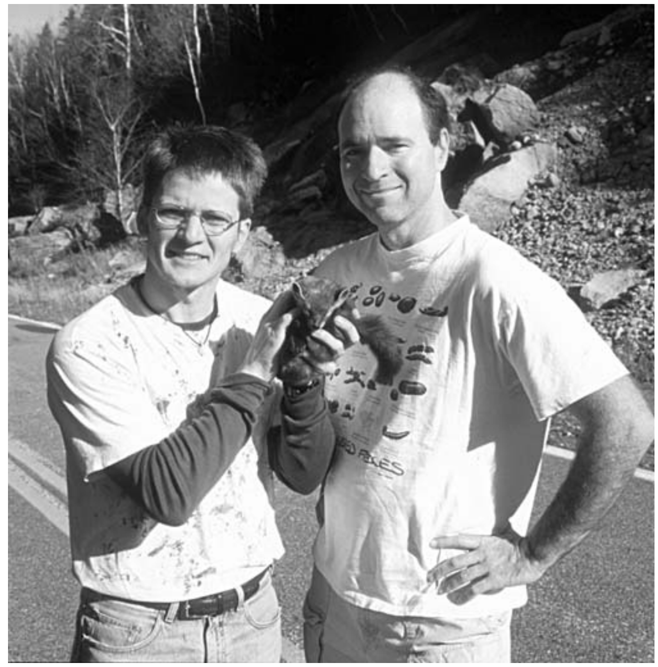

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