Evaluating Detection Probabilities for American Marten in the Black Hills, South Dakota

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ABSTRACT Assessing the effectiveness of monitoring techniques designed to determine presence of forest carnivores, such as American marten (*Martes americana*), is crucial for validation of survey results. Although comparisons between techniques have been made, little attention has been paid to the issue of detection probabilities (p). Thus, the underlying assumption has been that detection probabilities equal 1.0. We used presence–absence data obtained from a track-plate survey in conjunction with results from a saturation-trapping study to derive detection probabilities when marten occurred at high (>2 marten/10.2 km^2) and low ($\leq$1 marten/10.2 km^2) densities within 8 10.2-km^2 quadrats. Estimated probability of detecting marten in high-density quadrats was $p = 0.952$ (SE = 0.047), whereas the detection probability for low-density quadrats was considerably lower ($p = 0.333$, SE = 0.136). Our results indicated that failure to account for imperfect detection could lead to an underestimation of marten presence in 15–52% of low-density quadrats in the Black Hills, South Dakota, USA. We recommend that repeated site-survey data be analyzed to assess detection probabilities when documenting carnivore survey results. (JOURNAL OF WILDLIFE MANAGEMENT 71(7):2412–2416; 2007)

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Throughout their range, American marten (*Martes americana*) are associated with late-successional spruce–fir forests (Buskirk and Powell 1994). Due to their specialized nature and vulnerability to extirpation from logging, habitat fragmentation, and other alterations (Thompson and Harestad 1994, Minta et al. 1999, Potvin et al. 1999), marten presence has been used as an indicator of a healthy forest ecosystem (Bull et al. 1992, Buskirk 1992). Monitoring efforts designed to assess presence of marten have utilized a variety of techniques (e.g., snow-track surveys, line-triggered cameras, track-plate box surveys) with varying degrees of success (Bull et al. 1992, Foresman and Pearson 1998).

Zielinski and Kucera (1995) advocated for a standardized protocol when surveying for forest carnivores, such as American marten. This protocol established guidelines for 3 methods of detection: line-triggered cameras, snow-track surveys, and sooted-aluminum track plates. Although comparisons among these 3 techniques have been made (Bull et al. 1992, Forseman and Pearson 1998), to date little attention has been paid to the issue of estimating detection probabilities (however see Zielinski and Stauffer 1996). Thus, the underlying assumption has been that detection probabilities equal 1.0 (i.e., if the species is present it will be detected). Recently, several studies have shown that failure to account for imperfect detection can lead to biased estimates when dealing with presence–absence surveys (Gu and Swihart 2004, MacKenzie et al. 2005).

Due in large part to its ease of implementation and relatively low cost, one of the most commonly used methods to determine marten presence has been the sooted track-plate survey. It is often assumed that track-plate boxes exhibit higher detection probabilities when marten occur at higher densities (Ivan and Forseman 1999, Zielinski et al. 2001, Fecske et al. 2002). However, this assumption has never been rigorously tested. Our objective was to use recently developed analytical techniques for presence–absence data to estimate detection probabilities (p) when marten occurred at high and low densities.

STUDY AREA

Located in southwestern South Dakota and extreme northeastern Wyoming, USA, the Black Hills represent the easternmost extension of the Rocky Mountains (Froiland 1990). The Black Hills extend approximately 201 km north to south and 105 km east to west (Larson and Johnson 1999). Topography varied from steep ridges, rock outcrops, canyonlands, and gulches to upland prairie, rolling hills, and tablelands. Elevation ranged from 973 m to 2,202 m above mean sea level (Froiland 1990).

The Black Hills were dominated by a semi-arid continental climate type. However, the climate was highly variable, and it was influenced by a mountain climate type due to the rise in elevation above the surrounding plains (Froiland 1990). Precipitation ranged from <33 cm in the southern region to >72 cm in the higher elevations of the northwest (Larson and Johnson 1999). Mean daily temperatures were typically cooler in the northern Black Hills (–0.8–13.8° C) than in the southern Black Hills (0.5–6.9° C; Froiland 1990).

Ponderosa pine (*Pinus ponderosa*) was the most abundant tree species that occurred in the Black Hills and it comprised 84% of the forested landscape (Rumble and Anderson 1996). White spruce (*Picea glauca*) was the second most abundant conifer, occupying moist habitat at mid- to high elevations of the central and northern Black Hills. Other

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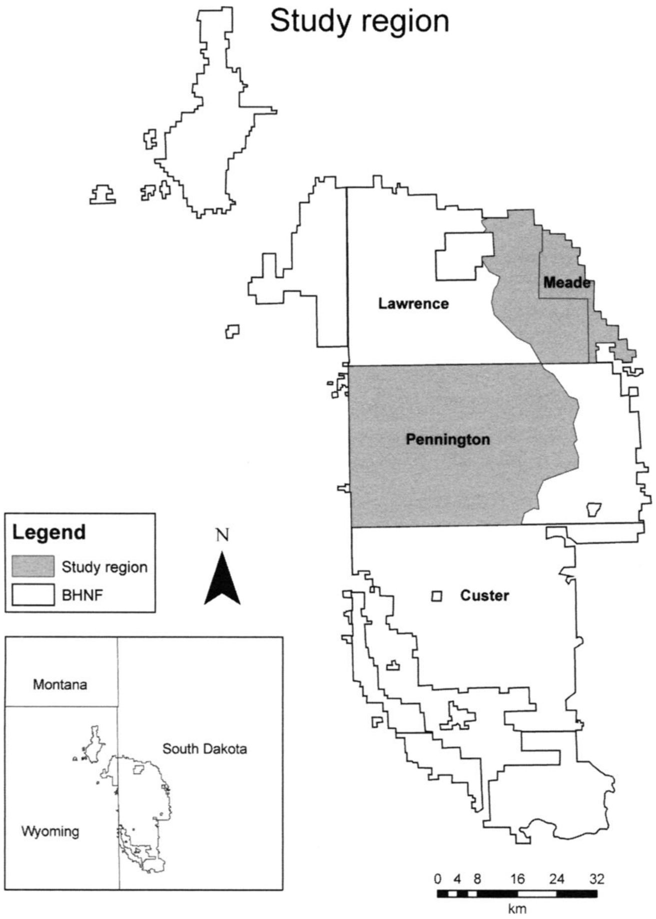

Figure 1. Map of Black Hills National Forest (BHNF) South Dakota, USA, with survey regions for American marten, 2005–2006.

important tree species included aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*), giving way to burr oak (*Quercus macrocarpa*) in the eastern and northern foothills (Larson and Johnson 1999).

We conducted our study in the northeastern and central regions of the Black Hills. The northeastern region covered approximately 532 km^2 and encompassed portions of Lawrence and Meade counties east of United States Highway 385. The central region site included portions of Pennington County west of United States Highway 385 and covered approximately 1,370 km^2 (Fig. 1).

METHODS

Track-Plate Surveys

We used a track-plate box survey (Zielinski and Kucera 1995) to determine presence or absence of marten within our study sites. Sample units were 10.2-km^2 quadrats as recommended by Zielinski and Kucera (1995). We selected quadrats based upon a previous model used to identify potentially suitable marten habitat (Fecske et al. 2002) and from field reconnaissance.

We placed 6 baited track-plate boxes within each 10.2-km^2 quadrat. We located boxes approximately 0.8 km apart in a loosely shaped grid (Zielinski and Kucera 1995), and we checked and rebaited them every 4 days for a 12-day period. We baited boxes with chicken and we placed a commercial lure (e.g., marten magic or skunk [*Mephitis mephitis*] essence [Otter Creek Lures, Stanley, WI]) on a nearby tree as a long-distance attractant.

Density Estimation

To estimate density within quadrats, we conducted a saturation-trapping survey in quadrats that successfully revealed marten presence. Otis et al. (1978) recommended that $\geq$4 traps be placed within an animal's estimated home range. Due to limited home range information for female marten in the Black Hills ($n = 2$; Fecske et al. 2002), we used a home range estimate for female marten in Wyoming of 5.96 km^2 (95% min. convex polygon estimate; O'Doherty et al. 1997), and placed 20 Tomahawk live-traps (Tomahawk Livetrap Co., Tomahawk, WI) approximately 0.8 km apart in each quadrat to exceed the recommended minimum trap density. We placed traps opportunistically within these guidelines.

We opened traps for 10 nights (200 trap-nights/quadrat) and baited and lured them similarly to the track-plate boxes. We placed traps at the base of trees or rocks and covered them with branches to provide security and thermal cover for captured animals. We checked traps daily, and we removed all captured animals from the trap, placed them in a restraining device, and injected them with ketamine hydrochloride (10 mg/454 g body wt; Fort Dodge Labs, Inc., Fort Dodge, IA). We ear-tagged, sexed, weighed, and aged all immobilized animals. We estimated age class based upon the degree of tooth wear (Strickland et al. 1982). We also fitted some animals with a 33.1-g radiocollar (Advanced Telemetry Systems, Isanti, MN). We returned immobilized animals to the trap until the effects of the drug were no longer apparent; we then released individuals at the capture site. The Institutional Animal Care and Use Committee at South Dakota State University approved all handling protocols (Approval No. 04-A030).

Analysis

We used results from the saturation-trapping study to group track-plate boxes into 2 categories: high- and low-density areas. We determined group membership based on the number of unique marten captured within each quadrat. The high-density group consisted of quadrats in which we captured $\geq$2 marten while the low-density group consisted of quadrats in which we captured $\leq$1 marten. We assumed a closed population during both the track-plate box and saturation-trapping surveys. We used the occupancy model of MacKenzie et al. (2002) in Program MARK (White and Burnham 1999) to estimate detection probabilities (p) when marten occurred at high and low densities at both quadrat (6 track plates = 1 unit) and track-plate box scale (track plate = 1 unit). We based model selection on Akaike's Information Criterion (Akaike 1973). In addition, we used the overall probability detection formula for k visits (i.e., $1 - [1-p]^k$; MacKenzie et al. 2006) to calculate the probability of detecting marten at least once during $k = 3$ visits at both the quadrat and box scales.

Table 1. Probability of detecting American marten in the Black Hills of South Dakota, USA, 2005–2006, at the track-plate[a] and quadrat[b] scale, ranked according to AIC_c[c] value.

	Models								
	p[d]		Psi[e]						
Scale	Density[f]	Constant[g]	Density	Constant	AIC_c	ΔAIC_c[h]	w_i[i]	K[j]	Deviance
Track-plate									
	X			X	198.728	0.000	0.731	3	192.341
	X		X		200.802	2.075	0.259	4	192.146
		X	X		207.234	8.506	0.010	3	200.846
		X		X	222.933	24.933	0.000	2	218.742
Quadrat									
	X			X	32.746	0.000	0.997	3	23.317
		X		X	44.173	11.427	0.003	2	38.673

[a] Track-plate = track-plate box as sample unit.
[b] Quadrat = 6 track-plate boxes as sample unit.
[c] AIC_c = Akaike's Information Criterion, adjusted for small sample sizes.
[d] p = probability of detection.
[e] Psi = probability of a site being occupied.
[f] Density = models varied by high (>2 marten) and low (≤1 marten) marten abundance within 10.2-km^2 quadrats.
[g] Constant = models were not varied by marten abundance within 10.2-km^2 quadrats.
[h] ΔAIC_c = difference in Akaike's Information Criterion value, adjusted for small sample sizes, relative to the top-ranked model's value.
[i] w_i = Akaike wt, corrected for small sample sizes.
[j] K = no. of estimated parameters in a model.

RESULTS

We surveyed 6 quadrats (NE = 3, Central = 3) from 20 January to 25 August 2005. We surveyed 2 additional quadrats in 2006, one from 3 to 14 January 2006 and a second from 27 June to 9 July 2006 (NE = 2). Number of detections registered at the quadrat scale ranged from 1 to 3, whereas the number of detections registered at the box scale ranged from 1 to 13. We conducted 6 saturation-trapping surveys from 31 May 2005 to 17 November 2005. We conducted 2 additional saturation-trapping surveys in 2006, one from 18 to 27 January 2006 and a second from 20 to 29 July 2006. We conducted saturation-trapping surveys 4 days to 7 months from track-plate box surveys. Number of unique animals captured within each quadrat ranged from 0 to 7.

Greatest support at both the quadrat and box scale was for models that allowed p to vary as a function of density (Table 1). At the quadrat scale (i.e., allowing 6 boxes to represent one unit) the parameter estimates from our top model revealed a 95% probability of detection over a 4-day period (p = 0.952, SE = 0.047) at high density, and a 33% probability of detection over a 4-day period (p = 0.333, SE = 0.136) when marten occurred at low density. At the box scale, parameter estimates from our top model revealed a 62% probability of detection over a 4-day period (p = 0.618, SE = 0.060) at high density, and a 7.5% probability of detection (p = 0.075, SE = 0.038) at low density (Table 2).

Our results revealed that over a 12-day sampling period, detection probabilities were approximately 1.0 in high-density quadrats (Table 2). We only observed one 4-day period in which the quadrat failed to detect marten in high-density areas. However, when marten occurred at low density, detection probabilities over the same 12-day period ranged from 0.48 to 0.85 (Table 2). Thus, failing to account for the issue of imperfect detection would have led to an underestimation of marten presence in 15–52% of low-density quadrats. We obtained similar results at the box scale. Over a 12-day period, each box had a 94% probability of detection in high-density areas, whereas boxes in low-density areas had a 21% probability of detection (Table 2).

DISCUSSION

Assessing the effectiveness of monitoring techniques designed to determine presence of forest carnivores is crucial for validation of survey results. Models that we applied to the data indicated that track-plate boxes were more effective at detecting marten when they occur at relatively high density (>2 marten/10.2 km^2) than at a low density (≤1 marten/10.2 km^2). Results from the high-density quadrats could potentially be biased high due to the relatively large number of marten captured in 3 of the 5 quadrats, and the fact that we surveyed these 3 quadrats twice. However, we conducted the repeated surveys 4–16 months apart, and thus, any habituation to the track plate would have been minimized. When we excluded repeated surveys from the analysis the probability of detection at the quadrat scale increased to 1.0 and the probability of detection at the box scale increased to 0.725 (SE = 0.066).

Due to logistical constraints, we conducted saturation trapping in 4 quadrats (high density = 1, low density = 3) 6–7 months post–track-plate box surveys. Results from quadrats with a substantial time lag mirrored those from the other 4 quadrats in which we conducted trapping <30 days from track-plate box surveys (i.e., one detection = 0 marten captured, multiple detections = >2 marten captured). It is possible the occupancy status within these quadrats changed given the time lapse between surveys, especially low-density quadrats, due to dispersing individ-

Table 2. Four and 12-day detection probabilities (p) and standard errors derived from track-plate box surveys of American marten in the Black Hills of South Dakota, USA, 2005–2006.

Scale	Density[a]	p (4 d)	SE	p (12 d)	(+) 1 SE	(−) 1 SE
Track-plate[b]	High[c]	0.618	0.060	0.944	0.967	0.914
	Low[d]	0.075	0.038	0.209	0.302	0.107
Quadrat[e]	High	0.952	0.047	1.000	1.000	0.999
	Low	0.333	0.136	0.699	0.850	0.482

[a] Density = marten/10.2-km^2 quadrat (results from saturation-trapping surveys).
[b] Track-plate = track-plate box as sample unit.
[c] High = quadrats with >2 marten.
[d] Low = quadrats with ≤1 marten.
[e] Quadrat = 6 track-plate boxes as sample unit.

uals. Nevertheless, marten were not harvested during our study and the parallel results obtained would suggest the temporal variation under which we conducted surveys did not affect our assessment of high- versus low-density quadrats.

In each low-density quadrat there was only a single detection registered at one track-plate box. We also failed to capture marten in any quadrat that exhibited this detection history with the saturation-trapping portion of the study. This low capture rate occurred despite the fact that in one quadrat, a radiocollared marten resided in the quadrat during both the track-plate survey and the saturation-trapping survey. It is unclear whether other quadrats that exhibited single detections were the result of transient marten passing through the quadrat, or whether the traps were less likely to capture marten than track-plate boxes. However, we experienced no difficulty in capturing marten in quadrats with multiple detections.

As the number of marten within a quadrat increased, detection probabilities and the number of detections over a 12-day sampling period also increased. This relationship between abundance and detection probability is fairly intuitive; however, failing to account for false absences in these low-abundance areas has the potential to bias inferences made from monitoring programs designed to assess species occurrence. Populations occurring at high densities would likely be readily identified; however, there exists a greater probability of overlooking potentially valuable corridor habitat, dispersed individuals, or populations that occur along the fringes or are disjunct from source populations. Failing to account for these low-density occupied areas has been shown to influence assumptions about extinction probabilities (Doherty et al. 2003, Alpizar-Jara et al. 2004).

Although it is unlikely that the number of animals available for detection will be known for many surveys, there are a variety of other factors that can contribute to discrepancies in detection probabilities. A study of swift fox (*Vulpes velox*) in eastern Colorado (Finley et al. 2005) demonstrated how detection probabilities were influenced by the time of year surveys are conducted. MacKenzie (2006) reanalyzed pronghorn (*Antilocapra americana*) data and illustrated how misleading results related to occupied patches were obtained when detection probabilities were positively associated with a specific habitat characteristic. These analyses further highlight the need to model occupancy in a way that accounts for detection probabilities that are <1.0.

MANAGEMENT IMPLICATIONS

Our results highlight the fact that inference on species distribution and abundance can be biased if analyses fail to account for false absences induced by low detectability. Although management of species must take into account overall goals and cost, we recommend that track-plate survey data be analyzed to assess detection probabilities to obtain more robust estimates of occupancy.

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