Winter Carnivore Survey Finds that Wolverines (*Gulo gulo*)are Likely Extirpated from Sequoia-Kings Canyon National Parks

Brian R. Hudgens[1]
David K. Garcelon[1]

[1]Institute for Wildlife Studies
PO Box 1104
Arcata, CA 95518
hudgens@iws.org

Abstract

Wolverines have disappeared from almost half of their range in North America. In California, no verified wolverine sightings have been reported in the last 50 years, although unconfirmed sightings in the southern Sierra Nevada, especially in Sequoia-Kings Canyon National Parks, provide doubt about the species' status in the southernmost part of its range. We determined that four animals in persisting in the parks corresponded to the minimum viable density necessary to have a persistent population since the last physical evidence of wolverines was recorded 25 years ago. To determine if a wolverine population persists in Sequoia-Kings Canyon National Parks, we used baited camera traps from January through May at high elevation sites throughout the parks. Our cameras took 602 pictures of animals over 1482 effective trap days. No wolverines were detected during our survey, although we did record other mesocarnivore species at 17 of the 18 bait stations. We conducted power analyses both to determine the effort required to have a high probability of detecting wolverines before setting up the survey and to interpret the absence of wolverine detections after the survey. Power analyses were based on trap efficiency estimates from studies in extant wolverine populations and movement simulations for a hypothetical wolverine population in our study area. We estimated that our survey had an 85% to >98% chance of detecting wolverines if as few as four animals persist in the park, which population models suggest would correspond to the minimum viable density. We conclude that it is highly unlikely that a viable population of wolverines persists in the southern Sierra Nevada, and that reintroduction would be the most appropriate conservation strategy for the species in this part of its range.

Introduction

The wolverine (*Gulo gulo*) is the largest terrestrial mustelid and one of the rarest mammals in North America. Prior to European settlement of North America, the geographic range of the wolverine extended from the north slope of Alaska and Canada through the montane ecoregions of southern California, Arizona and New Mexico (Hash 1987). Wolverines have disappeared from almost half of their former range (Paquet and Hackman 1995). At the southern limit of their historic range, the distribution is limited to montane regions and distinct gaps occur between subpopulations (Wilson 1982).

Wolverines historically occurred in the remote and high altitude areas of California, ranging from the northwestern part of the state to the southern Sierra Nevada (Grinnell et al. 1937, Schempf and White 1977). Wolverines were probably never numerous in California, due to their extensive home range size and the relatively small amount of suitable habitat in the state. Pressure from fur trappers may have further reduced wolverines to as few as 15 pairs by the 1930s (Grinnell et al. 1937).

There has been no specimen or photograph collected of a California wolverine for over 50 years, although there have been several unconfirmed sightings and reports of wolverines. It was believed that California's wolverine population may have increased during the 1960s and 1970s (Yocum 1973, Schempf and White 1977). However, this conclusion is based primarily on increased numbers of unconfirmed, and therefore potentially unreliable, sightings over this period. It is unclear whether greater numbers of sightings actually reflect a rebound of the California wolverine population during this time or simply reflect an increase in the numbers of people accessing the backcountry for recreation. Tracks photographed by Andrews (1980) during winter surveys in 1979 and 1980 represent the most recent physical evidence for the species persisting in California. Reported sightings of wolverines have dropped off sharply from the 1980s to the present.

The current status of the California wolverine is unknown. The California Department of Fish and Game lists the wolverine as present but threatened in the state. Reports of sightings in California have led some state and federal biologists to conclude that the California wolverine continues to persist (Graber 2006). On the other hand, the lack of physical or photographic evidence for the presence of wolverines has led other biologists to conclude that the species has been extirpated from California (Aubry and McKelvy 2005, Zielinski et al. 2005, T. Kucera pers. comm.). Several recent forest carnivore surveys conducted in California have failed to document any evidence of wolverines (Kucera & Barrett 1993, Zielinski et al. 2005, Green 2006). However, these surveys have been conducted during summer months when wolverines are less likely to be attracted to bait stations (Zielinski and Kucera 1995). The lack of physical evidence of wolverines from California is widely perceived as evidence that the species is extinct in the state (Zielinski et al. 2005, T. Kucera pers. comm.), although unsubstantiated wolverine sightings, mostly from Sequoia-Kings Canyon National Parks, conflict with this conclusion (Graber 1996, CDFG 2002). The concentration of unsubstantiated wolverine reports from Sequoia-Kings Canyon National Parks corresponds to the historic belief that the southern Sierra Nevada represents the last stronghold of wolverines in California (Grinnell et al. 1937, Zielinski et al. 2005). We believe that a winter survey is much more likely to detect wolverines than summer surveys, and that a concentrated effort in Sequoia-Kings Canyon National Parks would have a high probability of detecting wolverines if a population persists in the parks. In this paper we present the results of a wolverine survey conducted during winter 2006 in Sequoia-Kings Canyon National Parks designed to detect animals that may persist at a very low density.

The most difficult challenge of presence-absence surveys is interpreting negative results. An absence of wolverine detections could result from a real absence of wolverines in the study area, a failure of the survey mechanism to record the presence of wolverines, or insufficient power to detect wolverines that are present in the survey area. Our survey method of a baited camera station has been successfully used to detect wolverines in areas where they are known to persist (Copeland and Kucera 1997, Fisher et al. 2004, 2005, LeFroth et al. 2005) and other rare mesocarnivores in the Sierra Nevada (Zielinski et al. 2005, Green 2006). Nonetheless, we will look at whether our stations were successful at attracting and recording the presence of other mesocarnivores as evidence of their effectiveness.

A more difficult challenge is determining the power of our survey to detect wolverines, as they would occur at much lower densities than other mesocarnivores if they do persist in the park. The key to this analysis is information about the probability of detecting the species of interest (Pollock et al. 2004). Most statistical tools available to analyze survey power rely on applying detection probabilities estimated from surveys conducted in areas of known occupancy (e.g., MacKenzie et al. 2004, Peterson and Bayley 2004). In the absence of reliable information from surveys in known occupied habitats, detection probability can be estimated from simulation (Choquenot 2001 et al., Conn et al. 2004).

Detection probability may depend on a number of factors that vary between sites or through time. The most commonly considered variable is population density (e.g., MacKenzie et al. 2004, Peterson and Bayley 2004). Survey power may also be heavily influenced by the spatial distribution of the target species relative to survey effort (Choquenot et al. 2001, Pollock et al. 2004) and the attraction of survey stations within an animals home range (Choquenot et al. 2001). In our analyses we use a combination of previously reported detection probabilities and simulations to conduct a thorough power analysis incorporating the influence of wolverine density, spatial distribution and effective trap area.

Methods

Study species: Wolverines live in remote areas receiving large amounts of winter snowfall (Grinnell et al. 1937, Aubry and McKelvey 2005). They consume a wide variety of foods, including berries, mushrooms, amphibians, small mammals and carrion (Fry 1923, Grinnell et al. 1937). Small mammals and carrion comprise the most important parts of their winter diets (Hornocker and Hash 1981, Gustavsen et al. 2005, van Dijk et al. 2005). Adult wolverines maintain large home ranges (104 km^2-526 km^2 for females, 382 km^2-1522 km^2 for males; Magoun 1985, Banci 1987, Copeland 1996, Dawson et al. 2005). Wolverines typically have little or no home range overlap with other adults of the same sex, although male home ranges typically overlap with 2-4 female home ranges (Magoun 1985, Copeland 1996). Females begin breeding after age 2-3, producing litters of about 2 kits every 1-3 years (Persson 2003). Adult females with young reduce their winter home ranges, concentrating their activity around one or more den sites (Banci 1987). Wolverines dig dens into the snow, taking advantage of rock piles and fallen logs in open habitats (Pulliainien 1968, Raush and Pearson 1972, Magoun 1985). Young are weaned at 9-10 weeks and begin to travel with their mother by late May. Vangen et al. (2001) provide the best information on juvenile dispersal. Young males disperse from their mother's territory at approximately one year of age, but remain in their father's territory until they approach two years old. Young females typically disperse from their mother's territory after their second year (Persson 2003).

Study site:

We conducted this survey in Sequoia-Kings Canyon National Parks, California, USA. These parks represent the southern most extent of the wolverine's historic range in the Sierra Nevada. The parks are characterized by rugged mountains with 3076 km^2 of habitat above 2100 m and 1933 km^2 above 3000 m in the park boundaries, including Mt. Whitney, the tallest peak in the Continental United States at 4417 m. High elevation habitats in Sequoia-Kings Canyon National Parks include upper montane habitats dominated by lodgepole pine (*Pinus contorta*) and red fir (*Abies magnifica*), sub-alpine habitats dominated by whitebark pine (*Pinus albicaulis*), foxtail pine (*Pinus balfouriana*) and mountain hemlock(*Tsuga mertensiana*), and alpine habitat which is predominantly covered by tundra or barren rock. Winters at high elevations are characterized by heavy snowfall. During the winter of 2005-2006, snow survey stations within the park recorded maximum snow depths of 300 cm at 3250 m elevation. The greatest snowfall typically occurs in March, and heavy snowstorms are not uncommon in April. In 2006, snow accumulation was greater than snowmelt through May.

Results

Camera performance: Overall, the PIR triggered cameras worked very well under a wide range of conditions. We collected 2939 pictures during our survey in addition to pictures taken while surveyors set up, maintained and took down the stations. Pictures were taken during all hours of the day throughout the entire survey period. Most images were "empty", probably triggered by rapid increases in ambient temperature. Animals were visible in 602 pictures.

Survey results: No wolverines were recorded visiting any bait station. We did identify the nine species of mammals and three species of birds visiting survey stations. Martens (*Martes americana*) were the most common visitor, recorded in over 400 pictures from fourteen stations. Other mesocarnivore species recorded at survey stations included coyote (*Canis latrans*), fisher (*Martes pennanti*) , and black bear (*Ursus americanus*). In addition, one photograph was taken of an animal just outside the range of the camera flash that we believe to be a bobcat (*Lynx rufus*), although we cannot rule out the possibility that it was a coyote.

Sciurids were also common visitors to survey stations. Twenty-three pictures from three stations were taken of northern flying squirrel (*Glaucomys sabrinus*). Ten pictures of Douglas squirrel (*Tamiasciurus douglasii*) were taken from two stations and one picture of a golden-mantle ground squirrel (*Spermophilus lateralis*). Other mammals photographed included deer mouse (*Peromyscus maniculatus*) and white-tailed hare (*Lepus townsendii*)

We also recorded Clark's nutcracker (*Nucifraga columbiana*) and dark-eyed junco (*Junco hyemalis*) at survey stations. One camera (MK) knocked down by black bear recorded pictures of a green-tailed towhee (*Pipilo chlorurus*) and a white crowned sparrow (*Zonotrichia leucophrys*) bird species at the base of the tree between April 29 and May 10.

Preliminary Power analysis: Extinction probability was highly sensitive to both female reproductive rates and initial starting size (figure 2). Populations beginning with only 5 animals had a 50%->99% chance of extinction and are clearly not viable. Populations starting with 10 animals had a 30%-80% chance of extinction, while populations starting with 25 animals had a 0-50% chance of extinction. These results suggest that a minimal viable population is between 10 and 25 animals. We conservatively chose 10 interacting animals as the minimum viable population. Given a mean dispersal distance of 51 km (Vangen et al. 2001) wolverine density in the Sierra Nevada would have to be at least 1/817 km^2 (hereafter "target density") for 10 animals to be within the dispersal range of each other. This density corresponds to 4-5 animals living within the parks' boundaries, with other animals living in the wilderness areas north of the parks.

Based on the average trap efficiency from baited camera surveys in populations with known wolverine densities, we calculated that we would need an effort of at least 960 effective trap days. This effort corresponds to 16 stations set for two months.

Final Power Analyse: our survey had a greater than 95% chance of detecting wolverines if they persist in the park at densities greater than 1 animal/1300 square kilometers (figure 3).

Discussion

The key results of this study are that our survey was able to detect and record the presence of several species of mesocarnivores and that we did not detect the presence of wolverine. Although the power of this survey to detect wolverines depends on both wolverine density and the attraction radius of our baited survey stations, we had a low chance of missing wolverines under a wide range of conditions. The power of our survey under a variety of detection criteria, in conjunction with negative results from other surveys, lead us to believe that there is not a viable populations of wolverines within Sequoia-Kings Canyon National Parks, and that the species has likely been effectively extirpated from the southern Sierra Nevada.

The conclusion from this study that no viable population of wolverines persists in Sequoia-Kings Canyon National Parks is bolstered by negative findings from other recent carnivore surveys in the southern Sierra Nevada. Although the probability of wolverine attraction to baited survey stations is likely to be much lower in summer months, intensive mesocarnivore surveys by Zielinski et al. (2005) and Green (2006) had over 2000 trap-days of effort within the historic wolverine range with no detections. In addition, Kucera and Barrett failed to detect wolverines from 12 baited camera stations spread throughout the Sierra Nevada (T. Kucera unpublished report). A California Department of Fish and Game wolverine survey conducted in winter 2006 to the north and east of our survey, including one site in Kings Canyon National Park, also failed to detect any wolverines (C. Cotter, pers. comm.).

As with the studies mentioned above, we did record evidence of other mesocarnivore species in the southern Sierra Nevada. Our records include the highest known occurrence of coyotes in California. While removing camera stations we observed a coyote traveling across a 3500 m pass out of Dusy Basin. The abundance of mesocarnivores detected at high elevations in this study indicates that prey populations are also available at high elevations during winter months. This conclusion is bolstered by records of white-tailed hare, Douglas squirrels and flying squirrels at multiple stations.

This survey, in conjunction with other recent survey efforts, presents compelling evidence that wolverines have been effectively extirpated from the southern Sierra Nevada. We therefore believe the most appropriate management action for wolverines in California would be to re-introduce the species to the Sierra Nevada. A successful reintroduction would depend on sufficient, appropriate habitat being available for a population to persist. While a full evaluation of the potential for a successful reintroduction into the Sierra Nevada is beyond the scope of this paper, we note that the region includes an extensive, contiguous block of high-elevation protected habitat that supports a rich, if currently incomplete, native mesocarnivore community.

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Table 1. Studies included in estimation of trap efficiency.

Mulders et al. 2005
Krebs and Lewis 1999
Copeland 1996
Hornacker and Hash 1991
Inman unpublished report
Dawson unpublished report

Table 2. Location and availability of baited survey stations within Sequoia-Kings Canyon National Parks.

	lattitude			longitude							
site	degrees	minutes	seconds	degrees	minutes	seconds	Elevation (m)	last picture[1]	days closed	days available[2]	1st carnivore[3]
MK	36	26	11	118	35	21	2400	24-Apr	13	74	9-Feb
SP	36	28	32	118	16	2	3338	25-Mar	0	57	NA
RC	36	29	43	118	19	33	2955	11-May	0	104	29-Jan
CP	36	29	49	118	26	34	3161	9-May	16	86	3-Feb
GF	36	31	30	118	21	13	3234	10-May	0	103	26-Mar
TL	36	34	54	118	34	7	2839	21-Feb	0	25	7-Feb
WC	36	36	19	118	22	30	3311	10-May	0	103	28-Mar
TM	36	37	10	118	38	4	3149	11-May	20	84	27-Mar
TC	36	37	45	118	23	36	3165	11-May	0	104	30-Jan
BD	36	40	56	118	43	43	2773	26-Apr	4	85	31-Jan
MC	36	44	42	118	37	37	2154	7-Apr	4	66	1-Feb
CL	36	46	13	118	25	4	3268	10-May	6	97	5-Mar
BL	36	46	21	118	23	52	3260	4-May	0	97	7-Mar
GB	36	56	57	118	37	18	2505	16-Feb	0	20	7-Feb
HL	36	56	58	118	35	2	3092	24-Mar	4	52	5-Feb
MI	36	57	0	118	27	14	3290	10-May	0	103	29-Mar
DB	37	5	42	118	33	9	3450	13-Apr	0	76	29-Jan
EV	37	10	24	118	42	57	3012	20-Apr	1	82	23-Mar

1 Date last picture was taken.

2 Number of days between January 27 and date of last picture minus the number of days closed

3 Date first picture of any mesocarnivore taken at the station.

Table 3. Results from logistic regression on factors influencing the probability that at least one wolverine is attracted to at least one bait station in movement simulations.

Parameter	df	odds ratio	95% CI	p>Chi Sq
female home range	1	1.042	1.025-1.059	<0.0001
wolverines with home range in park	1	1.539	1.539-1.690	<0.0001
attraction radius	1	1.028	1.026-1.031	<0.0001

Figure 1. Map of baited survey sites with overlaying 20 km X 20 km grid. Labeled black dots indicate locations of baited survey stations, red stars indicate locations of unverified wolverine sightings reported to Sequoia-Kings Canyon National Parks (courtesy NPS) since 1980 (two northernmost stars indicate tracks reported by Andrews 1980).

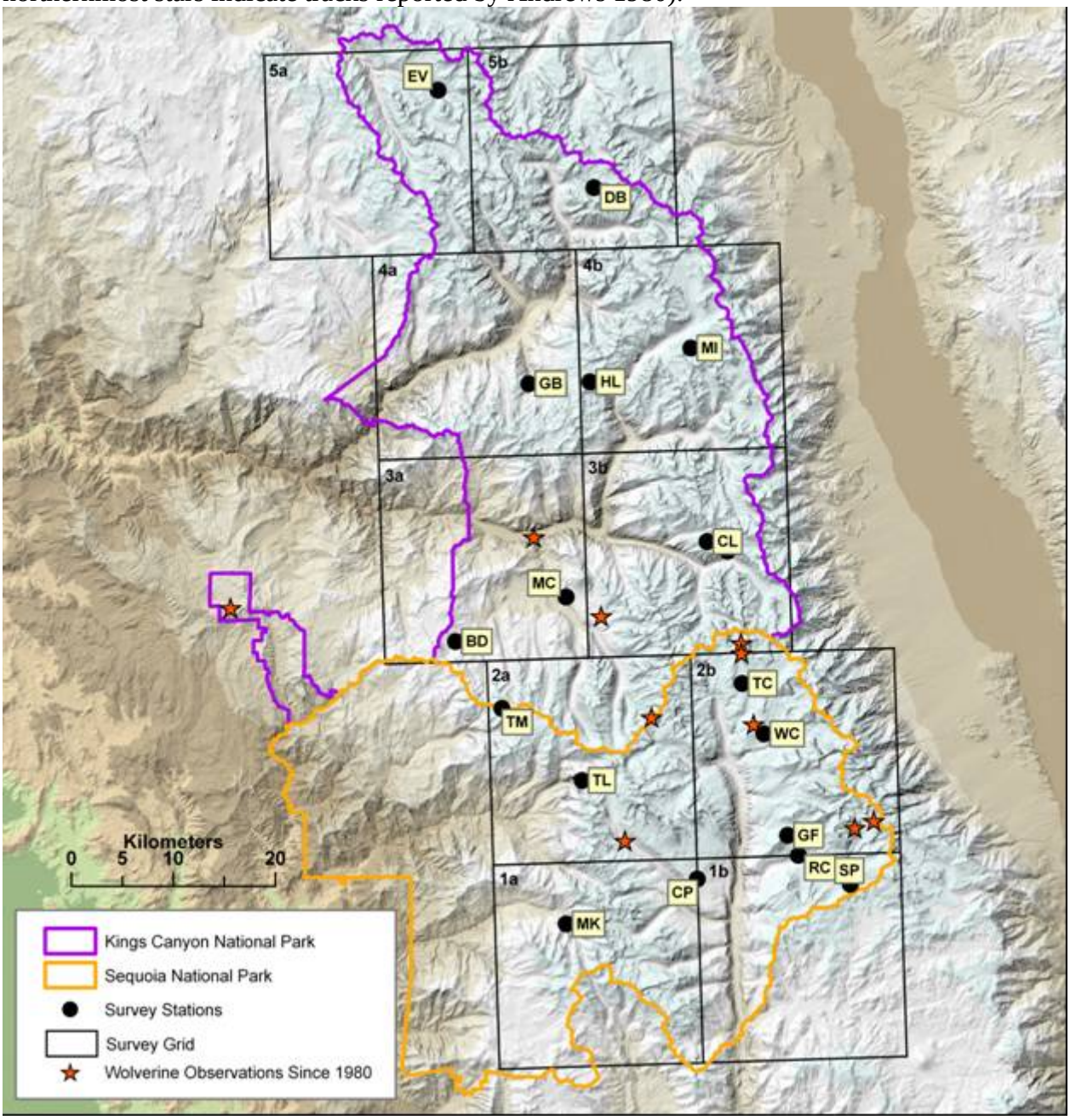

Figure 2. Probability of extinction within 25 yrs for wolverine populations in montane habitats. Each bar represents 1000 simulations at three productivity rates (kits/female/year), incorporating only demographic stochasticity.

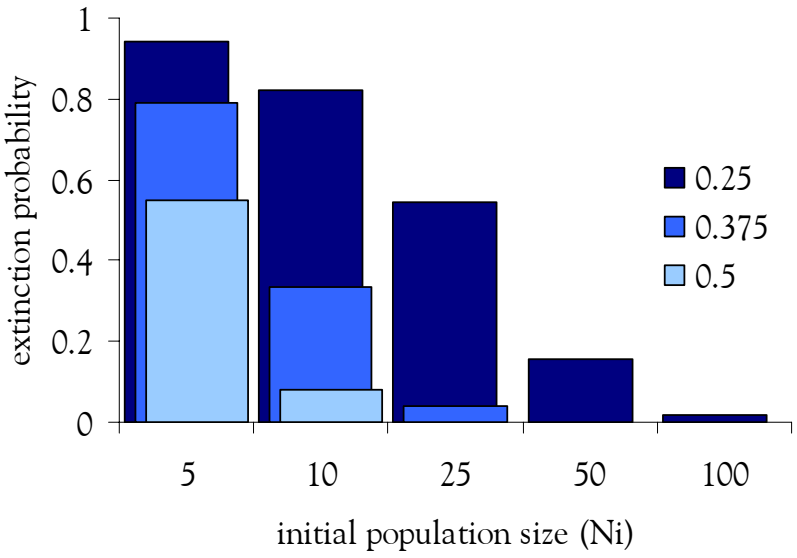
1
0.8
0.6
0.4
0.2
0
extinction probability
0.25
0.375
0.5
5
10
25
50
100
initial population size (Ni)

Figure 3. Probability of failing to detect at least one wolverine considering no acclimation to the survey stations and with acclimation. Target density represents minimum viable population (see text).

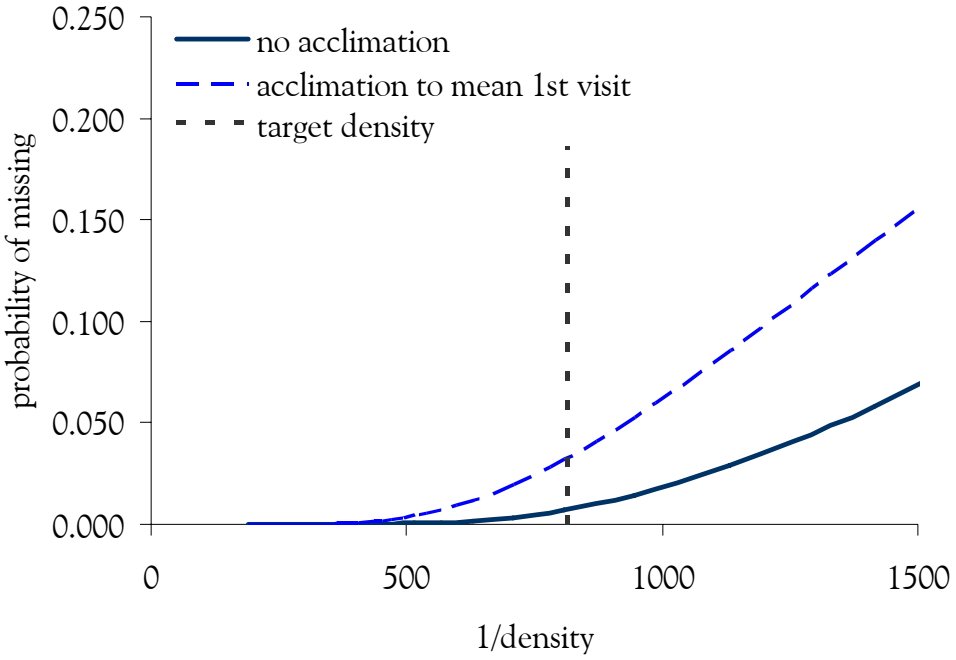

Figure 4. Detection probability from simulated surveys. Panels show the fraction of simulations with at least one "detection". Detections are defined as a wolverine passing within the attraction radius of a bait station.