

Estimating the density of Florida panthers using camera traps and telemetry – Report for Phase 1 of project

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INTRODUCTION

Recovery objectives as outlined in the Florida Panther Recovery Plan (USFWS 2008) have typically included an estimate of population abundance that must be reached to downlist or delist the endangered (Federal Register 1967) Florida panther (*Puma concolor coryi*). Obtaining a statistically defensible estimate of population size historically has not been feasible for Florida panthers (Sollmann et al. 2013a), even though it is currently highlighted as a critical parameter to assess the progress of recovery (USFWS 2008). There are various capture-mark-recapture methods (CMR) that can utilize either data from DNA hair snares or trail cameras to develop population estimates, and these have been effective for bears (Immell and Anthony 2008, Kendall et al. 2008) or felids (Karanth and Nichols 1998, Simcharoen et al. 2007) with uniquely identifiable fur coloration patterns. Unfortunately, preliminary testing has shown that panthers are not consistently attracted to DNA hair snares to make this a dependable method to obtain a robust population estimate, and it is not possible to reliably identify individual panthers in photographs via their fur (they are not spotted or striped) or morphological anomalies (e.g., notched ears, scars). These obstacles have similarly affected how managers attempt to estimate puma population sizes in the western United States, where they are typically determined using a mix of subjective information such as harvest data, sightings, or literature based estimates extrapolated to suitable puma habitat (Anderson et al. 2010).

The Florida Fish and Wildlife Conservation Commission (FWC), U.S. Fish and Wildlife Service (FWS), National Park Service, and their partners have relied solely on a minimum count index to track trends in the panther population since the 1980s (McBride et al. 2008). This method has provided the most consistent and reliable number for panther managers to assess changes in the population. That said, this technique does not provide a true population estimate, it does not have an associated measure of variance, and it does not take into account changes in detectability or sampling effort. In addition, it provides a minimum count, so the index is used with the understanding that a portion of the population is not accounted for.

Shindle and Kelly (2007) collected an expansive camera trap data set on panthers in the Picayune Strand State Forest in southwest Florida from 2005-2007. In 2010, FWC collaborated with David Shindle at the Conservancy of Southwest Florida (CSWFL) to initiate a scientific review of these camera trap data. The objectives of the review were to assess whether novel statistical techniques could be used within a CMR framework to derive a statistically defensible estimate of the panther population size from camera trap data, even with the aforementioned challenges associated with such data sets. Results of the review identified a spatial capture-recapture (SCR) model (Chandler and Royle 2013) that could permit an unambiguous density and abundance estimate of Florida panthers via camera trap data (Sollmann et al. 2013a). This technique relies on having

a portion of the panthers in the sampling area marked in a manner that is easily identifiable on camera trap photos (e.g., uniquely identifiable radiocollars, ear tags). In addition, the method also incorporates location data collected from VHF and GPS radiocollared animals; the resulting movement parameter can be used to further improve the model (Sollmann et al. 2013a).

Given these results —as well as subsequent work by Gardner et al. (2013) that identified a rigorous study design for trail camera trap deployment— FWC initiated Phase 1 of a feasibility study in 2014 in collaboration with U.S. Geological Survey and the CSWFL. Phase 1 involved collection of camera trap data from two camera arrays deployed on two parcels of public land in southwest Florida that are managed under different regimens (e.g., no public access vs. public access, intense prescribed burning program vs. limited prescribed burning). Photographic detections of all panthers (both marked and unmarked) were incorporated into a revised version of the model used by Sollmann et al. (2013a) to derive estimates of panther density for each study area.

METHODS

Study area and sampling methods

For Phase 1, two sampling sites were targeted for camera trap deployment (Figure 1): 1) The FWC-Addlands (FWC-ADD) study area, the focal site for FWC, was located within a portion of the Addition Lands Unit (hereafter noted as Addlands) of Big Cypress National Preserve (BCNP); 2) a camera trap array monitored by David Shindle from the CSWFL, the majority of which was deployed on the Florida Panther National Wildlife Refuge (FPNWR) but with a portion that extended into the Picayune Strand State Forest and the Fakahatchee Strand Preserve State Park. The FWC-ADD sampling site was closed to hunting during this study, although access to recreational users (hikers and camping) is permitted. There is the potential for permitting more broad-scale access and activities in the Addlands in the coming years, including off-road vehicle use and hunting. Hunting was permitted in the Addlands in the fall of 2014, after the completion of our study, for the first time since the acquisition of these lands in 1988. In turn, data collection on panthers and other wildlife via a camera trap array could serve to not only assist with estimating the density of panthers but also reveal any changes that may occur once access and use increases. The array deployed on the FPNWR (hereafter DS-FPNWR) primarily includes public lands where there is no hunting or public access. However, approximately 16% of this camera array included lands in the Picayune Strand State Forest that were open to the public and hunting.

Both study areas were the focus of recent panther capture efforts by FWC in order to try and increase the number of marked panthers (e.g., radiocollared, ear tagged) that would have a high probability of being detected on a camera trap array. The SCR methodology applied by Sollmann et al. (2013a) requires that a subset of the population is marked prior to initiating a camera trap study. Gardner et al. (2013) noted that having ≥ 5 marked panthers that utilize a portion of a sampling area will improve the precision of density estimates. During the current study, the FWC-ADD and DS-FPNWR sampling sites were being used by a minimum of 4-5 marked panthers as a part of their home range.

We deployed 50 camera traps in FWC-ADD in April 2014 within 50 grid cells that were 2.25-km on the x-axis and 2-km on the y-axis each (Figure 2). The DS-FPNWR site encompassed 86

trail cameras deployed in June 2014 within 50 similarly sized grid cells (Figure 3). The additional 36 cameras were part of a concurrent camera study on the FPNWR, but additional data provided by those cameras did not bias estimates of panther density. Each sampling site encompassed an area of 162 km². Stratification of grid cells due to inaccessibility or water levels was acceptable. This study design was developed following the recommendation of simulations completed by Gardner et al. (2013). Trail cameras were placed within grid cells at locations that were proximal to the center of the cell (Shindle and Kelly 2007). The inaccessibility of the centers of some grid cells (e.g., marshes with high water levels, tracts of inaccessible wetland forests or pinelands) sometimes resulted in the deployment of camera traps at locations away from the center of the cell. In most cases, camera traps were deployed along designated or historic ORV trails, game trails, or other sites where we could maximize the probability of capturing photos of panthers and other wildlife. Camera trap models used included the Reconyx HC500 (Reconyx, Holmen, Wisconsin, USA) or Cuddeback Attack (De Per, Wisconsin, USA) that were secured to trees approximately 45 cm above the ground (Shindle and Kelly 2007). Each camera trap location was georeferenced using a handheld GPS. Sampling duration for camera trap grids was continuous for a 4-5 month period. Camera trap sites were typically visited once per month after deployment to download photographs, check batteries and functionality, and trim surrounding vegetation. Each camera trap was uniquely identified via a pre-programmed alpha-numeric identifier that appeared on every photograph collected (e.g., trail camera ID and study area; FWC1_ADD), along with the date, time (all times EST), moon-phase, and temperature.

Photographs were stored in databases indexed by sampling site (i.e., FWC-ADD, DS-FPNWR) and photos collected from each camera trap were kept in separate folders. Photographs were reviewed in either Picasa 3 (Google Incorporated, Mountain View, California, USA) or Media Pro 1.4.2.44 (Phase One, Frederiksberg, Denmark) wherein photos of panthers were uniquely identified via their mark (radiocollar or ear tags) or were categorized as unmarked. We used the following rules to identify unique capture events of panthers from photographs:

1. Marked panthers (uniquely identifiable by radiocollars or ear tags)
 - a. Tally unique capture events only if photos of same marked panther are > 60min apart at a particular camera trap station. If a marked panther is photographed > 1 time at a particular camera site ≤ 60 min apart, these additional photographs are not considered unique capture events.
 - b. Different marked panthers photographed ≤ 60 min at a particular camera trap station are considered unique capture events.
2. Unmarked panthers
 - a. Tally unique capture events if photos of unmarked panthers are > 60min apart at a particular camera trap station.
 - b. If >1 unmarked panther is photographed at a particular camera trap station ≤ 60 min apart, these additional photographs are not considered unique capture events unless they can be positively identified as being different sex via the presence or absence of male genitalia.
3. Dependent aged kittens traveling with the dam are not tallied as unique capture events.
4. Photographs where the neck of the panther is not visible, and hence the marked status cannot be verified, are not counted as a unique capture event.

Data from marked and unmarked panther capture events were tallied in a spreadsheet for each camera trap station for each study site. Additionally, information regarding sampling effort (camera days) for each camera trap were recorded. Lastly, we compiled location data (GPS and

VHF locations) for marked panthers that used part or all of each study site as their home range.

Statistical analysis

The data associated with panthers detected by camera traps or telemetry were organized and stored in several spreadsheet files so that summaries of the data could be computed relatively easily for statistical analyses. We computed data summaries that were compatible with the R code developed by Sollmann et al. (2013a). More specifically, for the purposes of analysis, the detections of panthers were considered to have occurred during six consecutive survey periods, each of about 30 d duration, except for the final period, which included only 19 d. This partitioning of the entire period of sampling was necessary to fit the model described by Sollmann et al. (2013a). In reality, all camera traps deployed within the Addlands of BCNP operated continuously during the entire period of sampling (about five months). In future analyses (Phase 2), we will develop a statistical model that is consistent with the sampling protocol actually used in our camera trap surveys. For now (Phase 1), the data were analyzed using the model of Sollmann et al. (2013a).

A few modifications of the R code of Sollmann et al. (2013a) were needed to analyze the panther data. First, whenever the distance between a camera trap location and an individual's activity center was large, the code effectively assigned a zero value to λ (= expected number of encounters given distance between individual and trap). This assignment is innocuous provided the frequency of encounters y is zero; however, for any positive number of encounters, a value of $\lambda = 0$ causes an error because $\Pr(y > 0/\lambda = 0) = 0$ and the logarithm of this probability is undefined (since $\lim_{x \rightarrow 0} \log(x) = -\infty$), causing the R program to crash. As a workaround, we modified the code to assign λ an arbitrarily small, but positive, value in this situation.

The code of Sollmann et al. (2013b) was tailored to the shape of the spatial domain occupied by a raccoon population on a narrow barrier island oriented from southwest to northeast. Specifically, the proposal distribution for raccoon activity centers was restricted to locations within this island. To generalize the code for an arbitrary spatial domain, we modified the code to draw a sample from the uniform distribution in the vertical dimension of an unrestricted spatial domain.

One additional modification to the code of Sollmann et al. (2013a) was made based on theoretical considerations (Link, 2013). Instead of assuming a discrete-uniform prior distribution for population abundance N , we assumed a scale prior by assigning the model's hyperparameters as follows: $a = 10^{-6}$ and $b = 1$ (as opposed to $a = b = 1$).

We analyzed each data set using 100000 iterations of the Markov chain Monte Carlo (MCMC) algorithm described by Sollmann et al. (2013a). Examination of trace plots and autocorrelation functions provided no evidence of convergence problems; therefore, we estimated summaries (means, standard deviations, quantiles) of the posterior distribution using the final 80000 iterations of the MCMC algorithm. Monte Carlo standard errors of the estimates were computed using the subsampling bootstrap method (Flegal and Jones, 2010, 2011) with overlapping batch means of size $[\sqrt{80000}]$.

The spatial domain used in each analysis was obtained by adding a 45-km buffer beyond the boundary of the camera trap grid. The size of this domain was determined by fitting the model to larger and larger regions until the estimated density of panthers and other parameters stabilized.

RESULTS

A total of 7,849 camera trap days were recorded for 50 camera traps deployed within the FWC-ADD study site between April and September 2014. Eight marked panthers (some were transient) were documented on this study site from which we collected total of 416 and 1791 VHF and GPS locations, respectively. We collected 114 unique marked panther capture events and 131 unique unmarked panther capture events. A total of 12,863 camera days were recorded for 86 camera traps deployed within the DS-FPNWR site between June and November 2014. Four marked panthers were documented on this study site from which we collected a total of 254 VHF locations. Panther photographs included 71 unique marked panther capture events and 407 unique unmarked panther capture events.

The parameter estimates obtained by fitting the panther data from the FWC-ADD were quite similar to those obtained for panthers detected within the Picayune Strand Restoration Project (PSRP) area (Sollmann et al., 2013a). In particular, the estimated density of panthers and the estimated spatial scale of panther movements were nearly equal to those reported previously (Table 1). The data from 2014 did provide more precise estimates of the model's parameters, as is evident the posterior distribution of panther density (Fig. 4).

The parameter estimates obtained by fitting the panther data from DS-FPNWR indicated that panther density was considerably higher in this area (Table 2) than in FWC-ADD. Specifically, the estimated posterior mean was more than four times that estimated for FWC-ADD, and the amount of overlap between the posterior distributions associated with FWC-ADD and DS-FPNWR appeared to be negligible (compare Figs. 4 and 5). Estimates of the movement parameter σ were significantly lower in DS-FPNWR than in FWC-ADD (compare Tables 1 and 2), so the panthers telemetered in DS-FPNWR appeared to move less than those telemetered in BCNP.

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Table 1: Estimated summaries of posterior distribution for model fitted to Florida panther trail camera data from the FWC-ADD study site. Parameter definitions: D = panther density (no. per 100 km²), σ = scale parameter for range of panther movements (km), and $\lambda_0(t)$ = expected baseline encounter rate (no. per 30 d) of panthers during t th survey period.

Parameter	Mean	SD	Percentile		
			2.5	50	97.5
σ	3.95	0.05	3.85	3.95	4.05
$\lambda_0(t = 1)$	0.36	0.07	0.24	0.36	0.51
$\lambda_0(t = 2)$	0.59	0.08	0.44	0.59	0.76
$\lambda_0(t = 3)$	0.54	0.08	0.40	0.54	0.71
$\lambda_0(t = 4)$	0.27	0.05	0.17	0.27	0.39
$\lambda_0(t = 5)$	0.30	0.05	0.20	0.29	0.41
$\lambda_0(t = 6)$	0.33	0.07	0.21	0.32	0.47
D	1.37	0.47	0.59	1.32	2.42

Table 2: Estimated summaries of posterior distribution for model fitted to DS-FPNWR study site. Parameter definitions: D = panther density (no. per 100 km²), σ = scale parameter for range of panther movements (km), and $\lambda_0(t)$ = expected baseline encounter rate (no. per 30 d) of panthers during t th survey period.

Parameter	Mean	SD	Percentile		
			2.5	50	97.5
σ	3.17	0.10	2.98	3.17	3.38
$\lambda_0(t = 1)$	0.49	0.07	0.36	0.49	0.65
$\lambda_0(t = 2)$	0.37	0.05	0.28	0.37	0.48
$\lambda_0(t = 3)$	0.29	0.05	0.21	0.28	0.38
$\lambda_0(t = 4)$	0.20	0.03	0.14	0.19	0.27
$\lambda_0(t = 5)$	0.28	0.04	0.20	0.27	0.36
$\lambda_0(t = 6)$	0.50	0.08	0.37	0.50	0.68
D	5.91	1.30	3.61	5.84	8.68

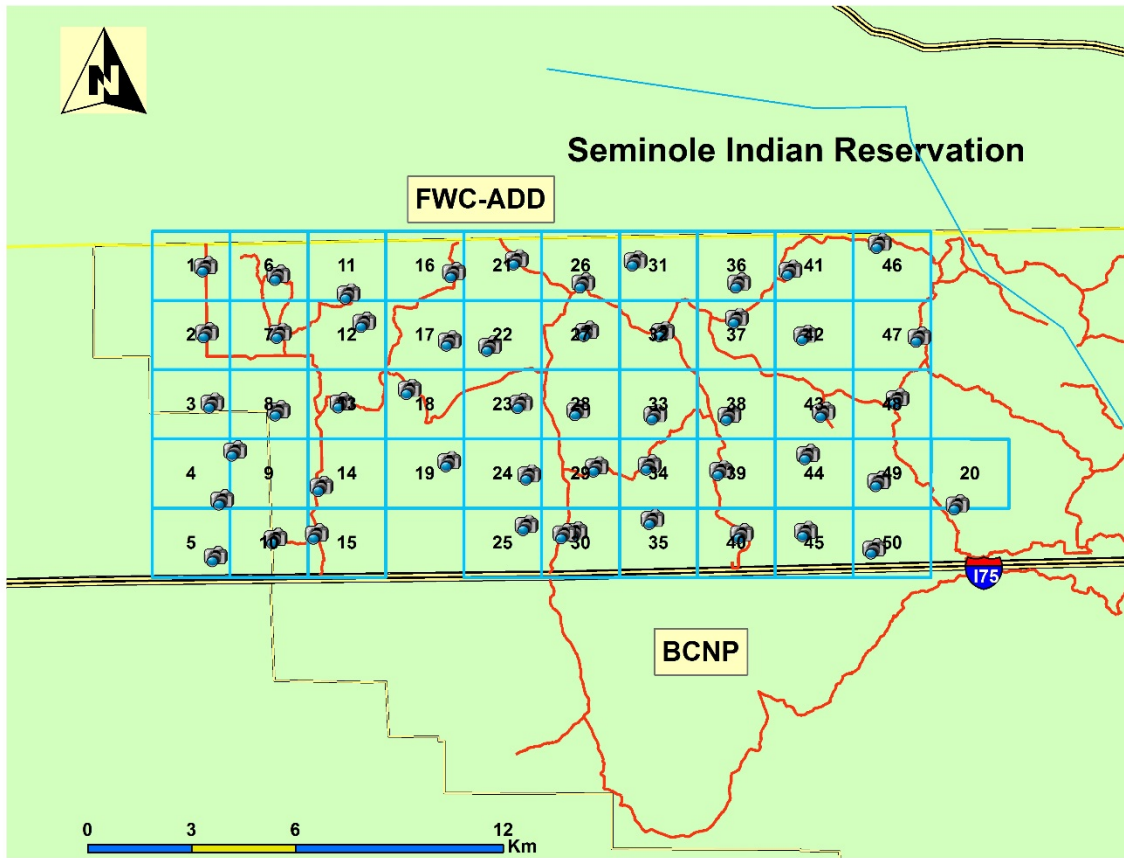


Figure 1. The locations of 50 camera traps deployed within the FWC-ADD study site in Big Cypress National Preserve (BCNP), Florida. Interstate 75 (Alligator Alley) serves as the southern boundary of the study site. The area of the camera trap grid was 162 km².

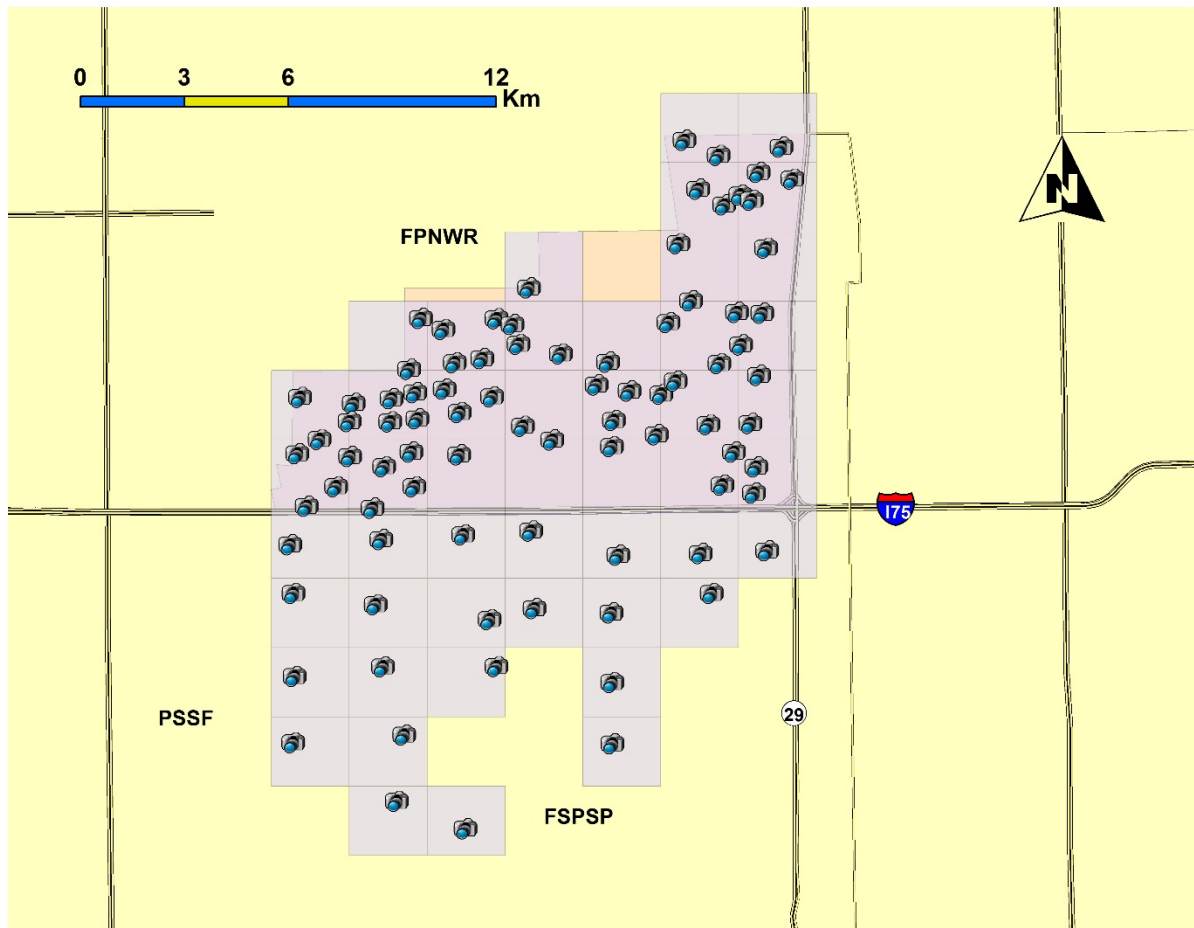


Figure 2. The locations of 86 camera traps deployed within the DS-FPNWR study site that encompasses the Florida Panther National Wildlife Refuge (FPNWR) as well as portions of the Picayune Strand State Forest (PSSF) and the Fakahatchee Strand Preserve State Park (FSPSP), Florida. Interstate 75 (Alligator Alley) intersects the camera trap grid, but this portion of the interstate is protected with continuous fencing and wildlife underpasses. The area of the camera trap grid was 162 km².

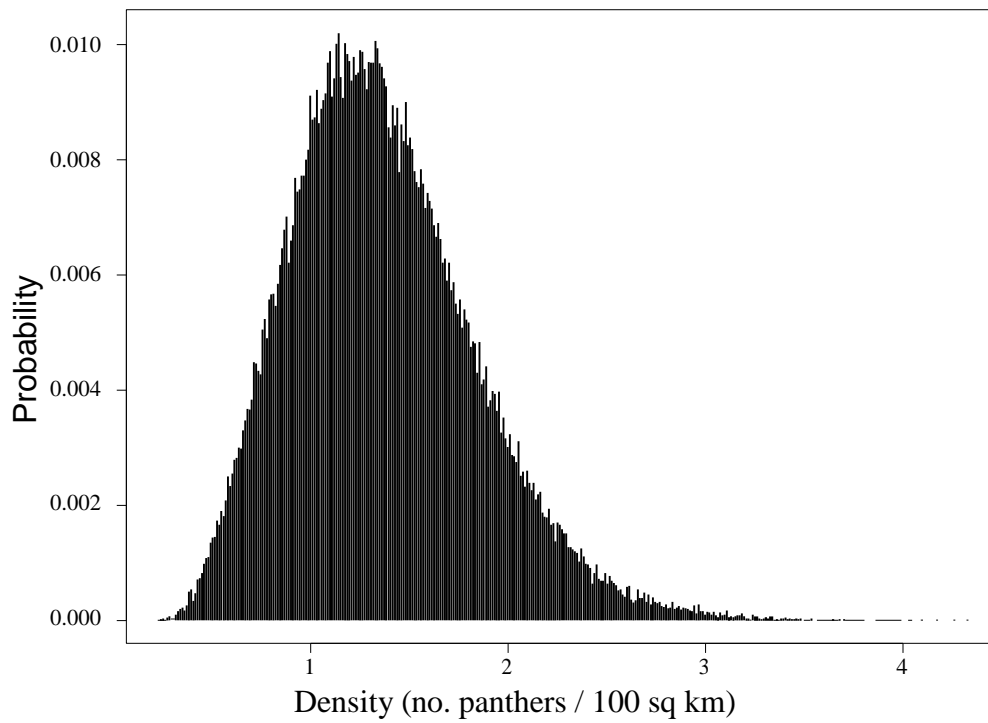


Figure 3: Estimated posterior distribution of panther density in the FWC-ADD study area within Big Cypress National Preserve, Florida.

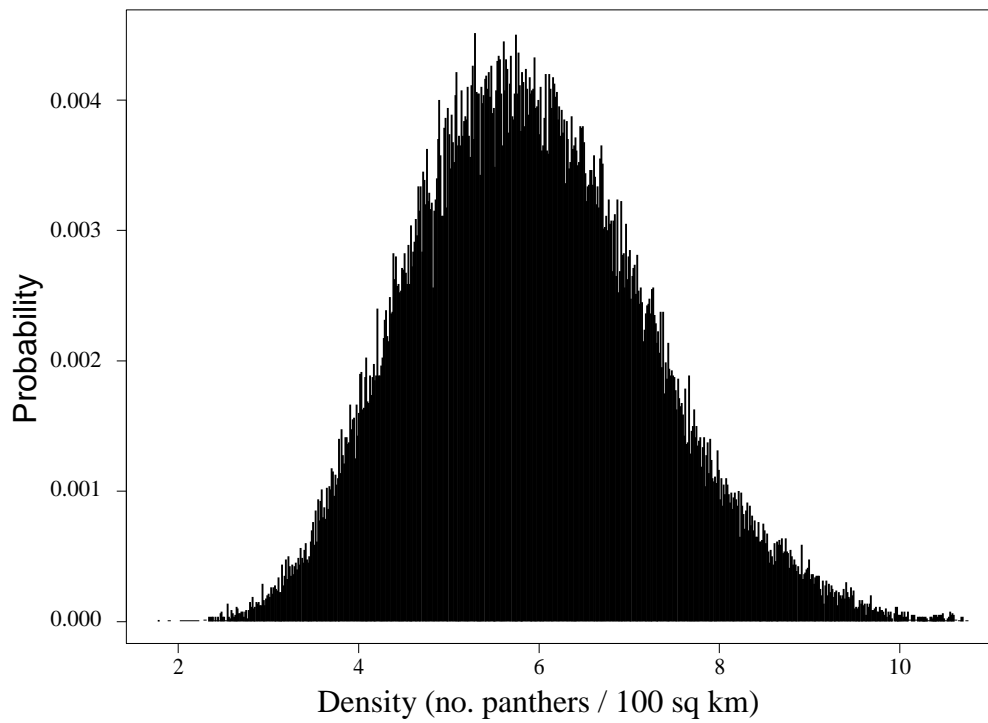


Figure 4: Estimated posterior distribution of panther density in the DS-FPNWR study area within the Florida Panther National Wildlife Refuge, Picayune Strand State Forest, and Fakahatchee Strand Preserve State Park, Florida.