Montana Lynx Monitoring Report: 2022–2023 Pilot Occupancy Survey

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Introduction

Canada lynx (*Lynx canadensis*) are a boreal forest associated meso-carnivore that ranges widely from Maine to Alaska, with the southern extent of its range extending into the northern regions of the contiguous United States. In 2000, lynx in the contiguous United States were designated as a Distinct Population Segment (DPS) and were federally listed on the Endangered Species Act (ESA) as threatened, based on a lack of regulatory mechanisms related to habitat management planning and lynx conservation on federal lands (U.S. Fish and Wildlife Service 2000). Since then, federal and state agencies have established land management regulations and practices to conserve lynx populations and habitat within the DPS (USFWS 2023). As part of these conservation efforts, the U.S. Fish and Wildlife Service (Service) designated critical lynx habitat across key portions of their range. As part of a settlement agreement in 2015, Montana Fish, Wildlife and Parks, (FWP) created lynx protection zones (LPZs) based off the critical lynx habitat designations in northwest Montana and the Greater Yellowstone Ecosystem (GYE; Figure 1). Within the LPZs, specific recreational trapping regulations were established to mitigate the non-target capture of lynx.

In 2019, FWP collaborated with the Service and other state wildlife agencies to develop a Post-Delisting Monitoring Plan (PDMP) for lynx in Montana. The PDMP established a statewide lynx monitoring program with “triggers” designed to indicate when the population had declined beyond normal cyclic lows, requiring management intervention to ensure persistence. Due to litigation against the USFWS, efforts to delist lynx from the ESA were discontinued along with further development of the PDMP. In 2022, the USFWS started gathering data to update the 2018 Lynx Species Status Assessment (SSA) and announced their plans to re-evaluate lynx critical habitat within the LPZs beginning in late 2023. Information pertaining to the status of lynx across Montana could help guide the future decision-making process regarding delisting and the maintenance of LPZs. In response, FWP developed a lynx monitoring protocol to initiate the investigation of lynx occupancy in Montana. The survey design was based off the original PDMP with some additions to further inform the USFWS's reassessment of lynx critical habitat in the Greater Yellowstone Ecosystem (GYE).

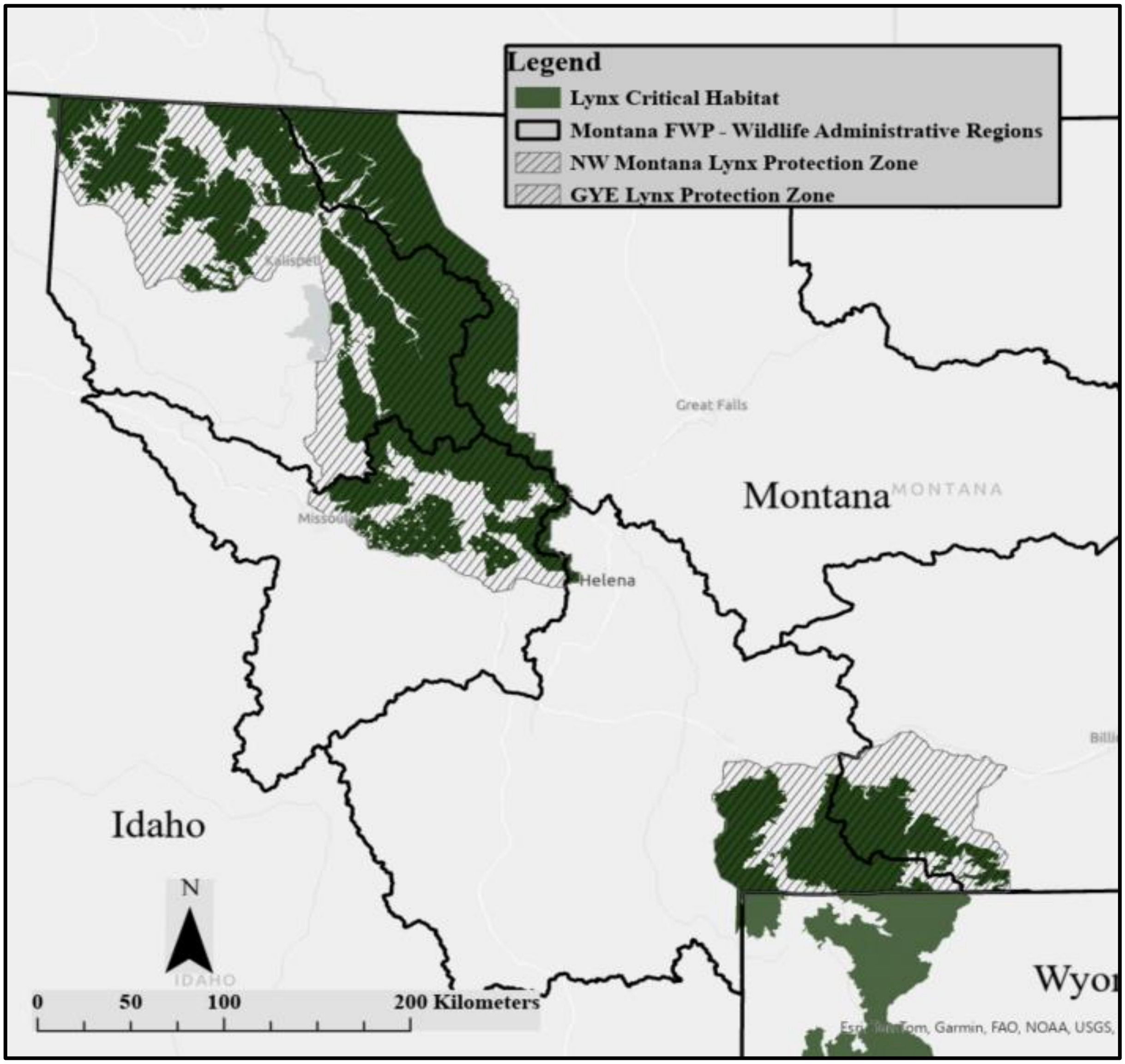

Figure 1. Lynx critical habitat designation and lynx protection zones (LPZ's) in Montana, USA, 2015–2023.

Within Montana, lynx have been documented throughout the Rocky Mountains, from the Canadian border to Yellowstone National Park (Interagency Lynx Biology Team 2013, Anderson 2022). Recent habitat quality models based off temperature and precipitation covariates suggest that high quality lynx habitat exists primarily in FWP Administrative Regions 1, 2 and 3 with concentrations in the far northwest corner of the state, the Seeley-Swan area, and the GYE (Figure 2; Olson et al. 2020). In Montana, lynx predominantly maintain breeding populations within the largest blocks of high-quality habitat (hereafter referred to as core areas; Squires et al. 2013); however, irruptions of lynx in Canada occasionally flood Montana with lynx, increasing occupancy in marginal habitat (Linden et al. 2011). Because lynx do not persist well in marginal habitats, populations recede, leaving behind "tidepools" of lynx in core habitat areas (McKelvey et al. 2000, Squires et al. 2013). This ebb and flow of lynx populations is a function of natural range edge effects, as well as cyclic population fluctuations in concert with snowshoe hare populations, the lynx's primary prey species.

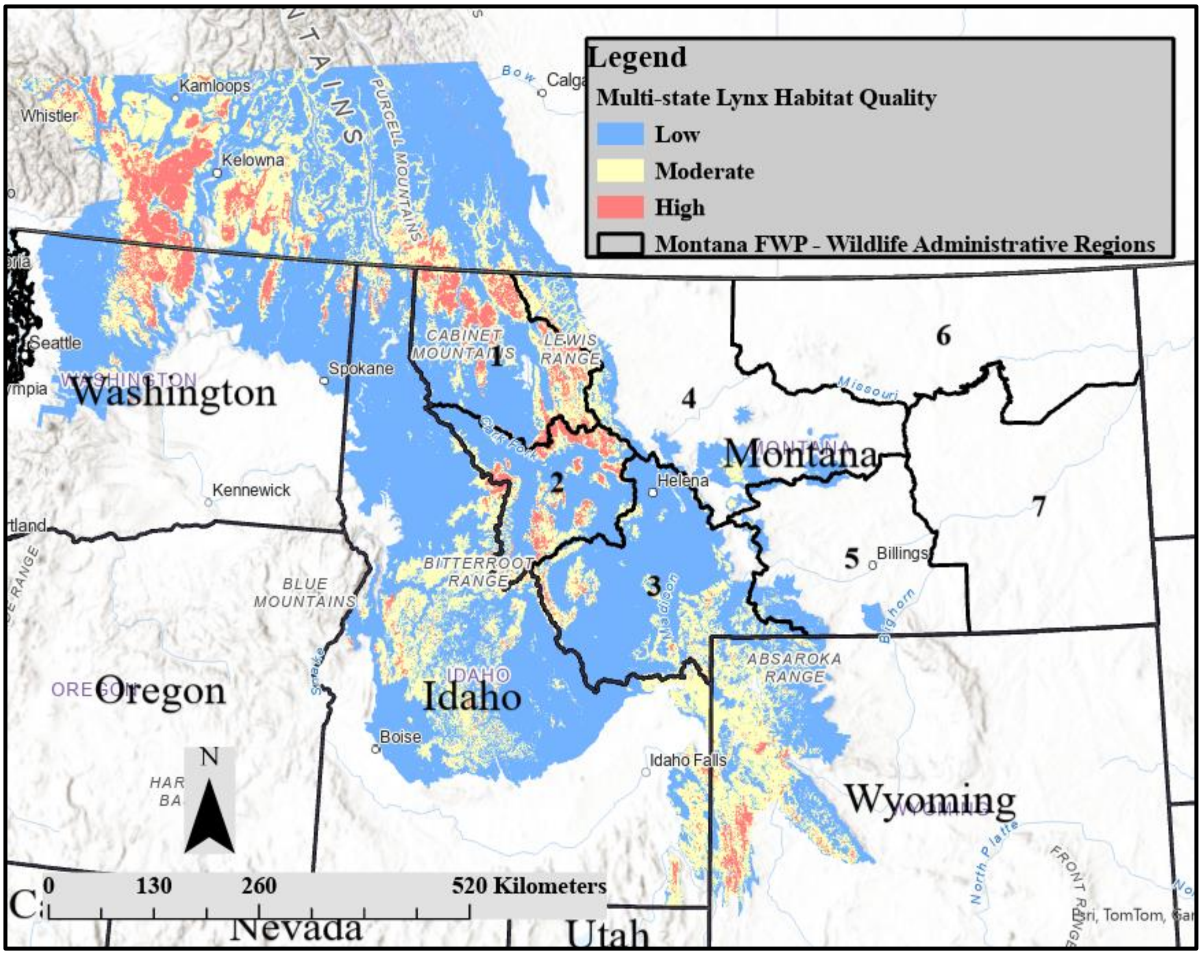

Figure 2. Categorical spatial predictions of Canada lynx habitat quality in northwestern United States and southwestern Canada as depicted in Olson et al. (2020).

To ensure the conservation of lynx in Montana and the greater DPS, baseline population status information is needed. Monitoring carnivore populations, such as lynx, can be difficult as they are often cryptic, exhibit crepuscular activity patterns, and occur at low densities across large spatial scales (Wilson and Delahay 2001, Kolbe and Squires 2007, Squires et al. 2012). Occupancy is a natural state variable that has been used to evaluate species distributions and ranges, as well as species-habitat relationships (Bailey et al. 2004, Ball et al. 2005, Karanth et al. 2010, Zylstra and Steidl 2009). In large-scale monitoring programs for cryptic species, occupancy is sometimes used as a surrogate for abundance (MacKenzie et al. 2006). Since occupancy models account for imperfect detection, models produced from occupancy work can help predict where species may or may not be present and their relative abundance in relationship to modeled covariates.

Currently, there is limited information on lynx occupancy and distribution in Montana. Developing a rigorous monitoring program focusing on core areas that support breeding populations of lynx will benefit the management and conservation of lynx populations in Montana in several ways: 1) understanding how probability of occurrence varies in relation to habitat will help managers predict changes in occupancy in core areas due to large-scale habitat changes; 2) monitoring population distribution will help managers better understand the role of marginal habitat in natural population fluctuations; and 3) understanding how occupancy of lynx in marginal "tide pool" habit areas, such as the GYE, compares to core habitat areas in other parts of the state will help evaluate the importance of areas, like the GYE, to the overall conservation of lynx in Montana.

The primary objectives of this project were to 1) establish a sampling framework that can be used to determine trend in lynx occupancy in Montana over time, 2) evaluate methodology to detect lynx using remote cameras and automated scent dispensers 3) compare probability of lynx occurrence between predicted high quality habitat in northwest Montana and lower quality habitat in the GYE, and 4) utilize results from the occupancy analysis to verify the power of future monitoring efforts to detect population change.

Methods

Study Areas

Core Habitat:

These areas of Montana are composed of large expanses of high-quality lynx habitat as defined by Olson et al. (2020) and hold Montana's primary resident lynx population. High-quality habitat can be characterized as a forest mosaic with dense, horizontal cover that is highly conducive to supporting snowshoe hares (*Lepus americanus*).

Greater Yellowstone Ecosystem:

The GYE is composed of lower-elevation valleys that contain short-grass prairie and sagebrush communities that transition into fragmented tracts of forests containing increasing levels of horizontal cover at higher elevations. This area contains a low level of lynx habitat that does not appear to support long-term resident lynx populations. The GYE is occasionally used as a travel corridor during lynx irruptions from Canada and by transient animals (Squires and Oakleaf 2005, Murphy et al. 2014).

Sampling Frame – Objective 1

To determine a sampling frame for this project and future monitoring efforts, we overlaid a 7.5-km x 7.5-km grid over Montana. The 56.25-km^2 grid cell size is roughly equivalent to the home range size of a resident female lynx (Ruggiero et al. 2000), and the grid is nested within a larger 15-km x 15-km grid established for a multi-state, wolverine monitoring program designed for monitoring wolverine occupancy in Idaho, Montana, Washington, and Wyoming (Lukacs et al. 2020). We then defined the 180 cells that contained > 50% high-quality lynx habitat (Olson et al. 2020) as core habitat (10,125 km^2; Figure 3). Within the GYE, we identified cells that contained any proportion of high-quality habitat (n = 63; Figure 4).

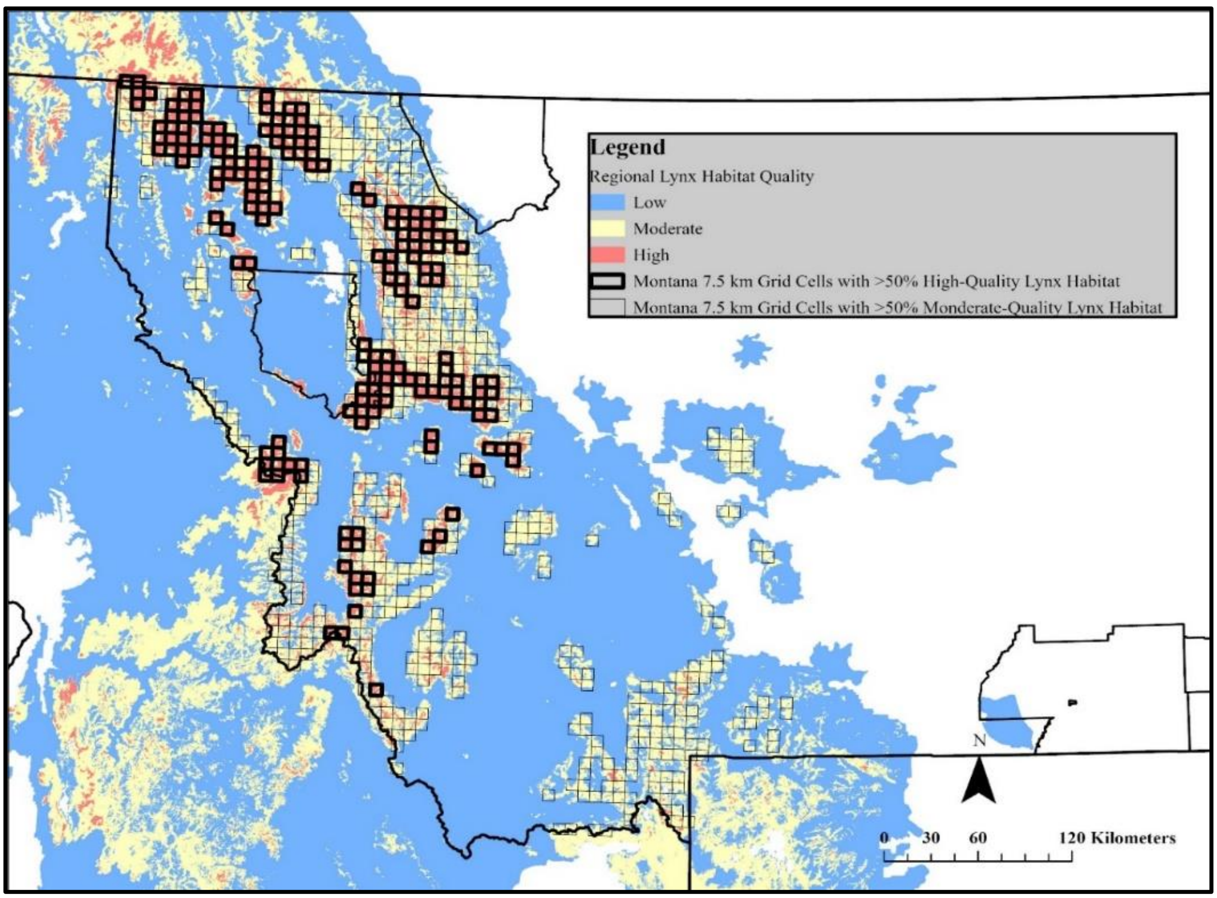

Figure 3. The sampling frame for lynx occupancy monitoring in Montana, USA determined by 7.5-km x 7.5-km grid cells that were >50% high quality lynx habitat according to a data rich and scientifically rigorous regional habitat model produced by Olson et al. (2020).

Based on lynx occupancy work in similar habitats in Colorado, we estimated an occupancy rate (*psi*) of approximately 0.45 with a detection rate (p) of 0.40 within core habitat in Montana (J. Ivan, Colorado Parks and Wildlife, personal communication). To evaluate these assumed rates, we randomly sampled 20 cells (1,125 km^2 total area) within the core habitat study area in FWP Regions 1 and 2 (Figure 4).

Areas within the GYE have limited high-quality lynx habitat but have contiguous areas of moderate-quality habitat extending from the boundaries of Yellowstone National Park. Assuming occupancy rate is ≤50% of that estimated for high-quality habitat (psi ≤ 0.225) and detection stays constant (p = 0.40), sampling 20 cells within the GYE should yield a 99% CI to be approximately ±0.10 of detecting a lynx if the area is occupied (J. Ivan, Colorado Parks and Wildlife, personal communication). Therefore, within the GYE study area, we selected 20 cells that had the highest proportions of high-quality lynx habitat (0.04–0.30; Figure 4).

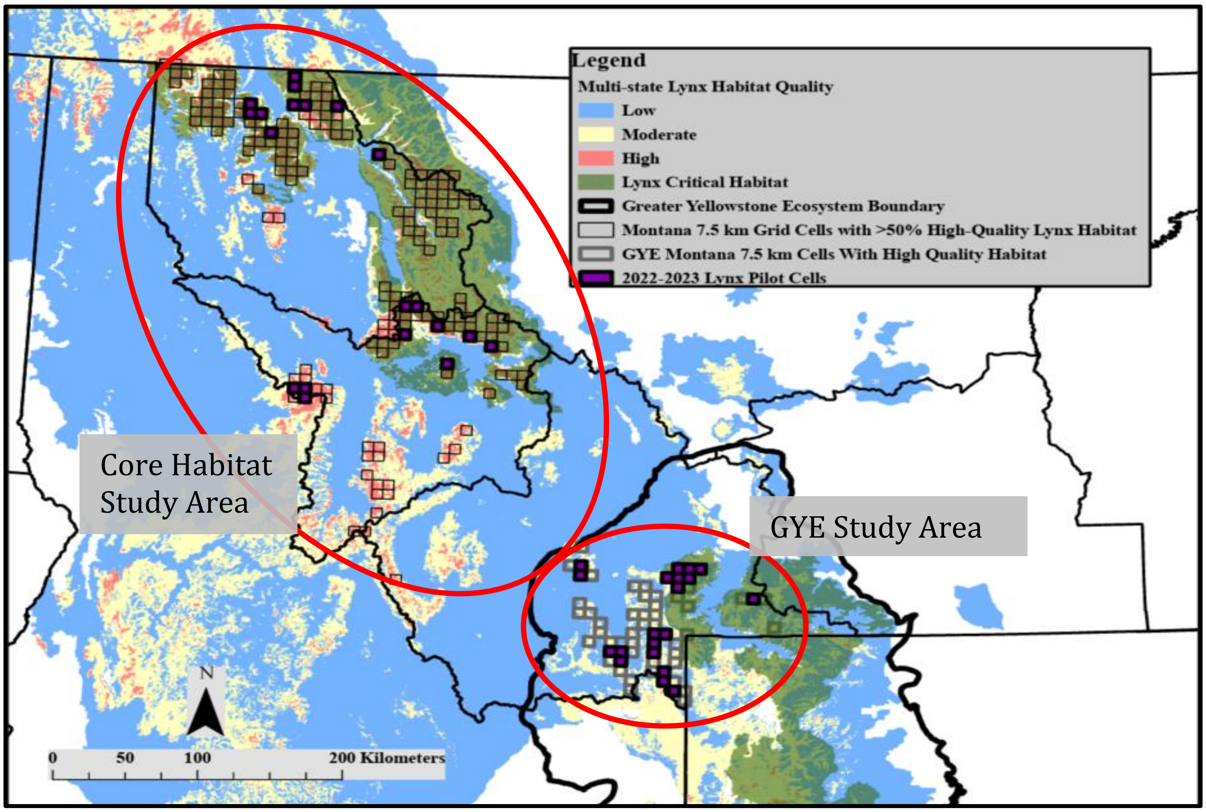

Figure 4. Montana cells sampled for lynx pilot occupancy survey from 1 December 2022–29 April 2023, within core, high-quality lynx habitat (*n* = 20) and within marginal, high-quality habitat within the GYE (*n* = 20). Sample locations generated along a trail or road within high-quality lynx habitat.

Field methods – Objective 2

Within each of the 40 cells selected across the 2 study areas, we placed a lynx monitoring station. To increase detection probability, stations were place near a trail or road (Scully et al. 2018, Anderson 2022) in high-quality lynx habitat with specific locations focused on areas with dense horizontal cover, away from highly human traveled routes. Stations were equipped with an automatic scent dispenser, a visual attractant, and a remote camera to determine lynx presence/absence. Monitoring stations were fashioned after those deployed in previous meso-carnivore monitoring programs for wolverine and fisher

(Krohner et al. 2019, Lukacs et al. 2020). Stations operated over 5, 30-day sampling occasions from 1 December 2022–29 April 2023 to ensure that the sampling period overlapped the lynx breeding season (March and April), when detection probabilities are the highest (Crowley et al. 2013).

To attract lynx to the station, we used a combination of scent and visual attractants. A scent dispenser, containing a mixture of beaver castor and catnip oil, was placed 12–15 ft above ground level in a living tree with >30 cm dbh and isolated from surrounding trees by at least 1.5 m. The dispenser was programed to emit 3 mL of lure every 24 hours. We hung a compact disk (CD) as a visual attractant between the closest trail or road and the scent dispenser tree (McDaniel et al. 2000, Nielsen and McCollough 2009). The use of scent dispensers did not impact detection probabilities of other mesocarnivore species compared to using baited stations (Lukacs et al. 2020). Using dispensers instead of bait greatly reduces the amount of field work needed to run a monitoring station, since scent dispensers only required two visits to the station each year: deployment and retrieval.

We deployed a Reconyx PC800 HyperFire 2 Professional Covert IR camera (RECONYX Inc., Holmen, Wisconsin) at each station. Cameras were fixed to a nearby tree, 5–6 m from the scent tree, and positioned north to capture animals at the scent tree. Cameras were programed to take a series of 3 rapid-fire pictures with no delay between photos. In addition, a time lapse picture was taken every day at 11:00 a.m. to ensure proper camera function. All photos collected were stored and categorized using Colorado Parks and Wildlife Photo Warehouse software (Newkirk 2015, Ivan and Newkirk 2016).

Lynx occupancy and detection probability analysis

Using Package unmarked (Fiske and Chandler 2011, Kellner et al. 2023) in Program R version 4.3.0 (R Core Team 2023), we estimated occupancy and detection rates for lynx within the sampling frame in Montana using a single season occupancy model (Fiske and Chandler 2011, Kellner et al. 2023). The occupancy models used constant detection rates for 30-day encounter occasions from 1 December–29 April during the 2022–2023 sampling period. Occupancy models included a constant model and two models to compare the occupancy rates between study areas: 1) a site-specific model that compared core lynx habitat (core habitat study area) to lower quality habitat cells sampled in the GYE study area, and 2) a habitat model with the proportion of the cell classified as high-quality habitat. Model fit (Akaike Information Criteria corrected for small sample sizes; AICc) was estimated from package AICmoavg (Mazerolle 2023) in Program R version 4.3.0 (R Core Team 2023).

Power analysis

The goal of continued monitoring in Montana is to be able to detect a 50% change in lynx occupancy within core habitat at 5-year intervals. Due to the inherent boom-bust cycle of lynx populations in response to snowshoe hare abundance (Ward and Krebs 1985), a threshold of a 50% decline in the occupancy rate in high-quality habitat would trigger the need for further conservation efforts. We simulated occupancy data using different occupancy rates and 5 encounter occasions for the 180 potential sites, with 100,000 simulations per analysis. The simulations used the most conservative detection rate estimate from the occupancy analyses. Alpha was set to 0.05. A theoretical 50% decline in occupancy was calculated from the estimated occupancy rate for core habitat from the site-specific occupancy model.

Results

Camera effort and species detections

We deployed a total of 40 monitoring stations across the 2 study areas (20 stations in each) from 1 December 2022–29 April 2023 for a total of 6,000 trap nights (5 sampling occasions of 30 trap nights for 40 cameras). Of the trap nights, 4,935 nights had no lynx detections, and 24 nights had at least one lynx detected. For the remainder of the trap nights, the cameras were inactive for a variety of reasons, including theft, late deployment of cameras, and on-site disruptions. In the core study area, one camera was stolen and not recovered. A total of 53,664 images were captured at 39 of the 40 stations deployed across the two study areas. Most lynx detections (8 nights of detections) occurred during the final sampling occasion, 31 March–29 April, which coincided with the peak lynx breeding period.

A total of 188 photos of lynx were captured at 11 out of 19 of the sites in core habitat study area. No lynx were detected at the 20 monitoring stations in the GYE study area; however, we received 2 verified lynx photos from a member of the public during the survey period in the Moonlight Basin area of the GYE (Figure 5). A total of 22 wildlife species were detected, with red squirrels being the most highly detected species (3,323 photos) followed by marten (2,980 photos). We also captured 921 photos of wolverines across all study areas. Individuals were often captured in multiple photos, and each photo did not equate to a different individual. Specific individuals were not identified in this survey.

Lynx occupancy – Objective 3

The estimated occupancy for all sampled cells, regardless of study site or habitat, was 0.37 (SE = 0.10) and detection probability was 0.30 (SE = 0.077) for a 30-day sampling occasion with the constant occupancy model. For 5 sampling occasions, the estimated cumulative detection rate was 0.83 for the constant occupancy model. The site-specific model had the best fit of the 3 occupancy models, with an AIC_c of 97.29 (K = 3). Lower AIC_c values indicate the model has more support from the data and indicates the most parsimonious model (Anderson 2008). The habitat model was competitive (Δ AICc = 2.23, K = 3), but the constant model was not competitive (Δ AICc = 18.81, K = 2).

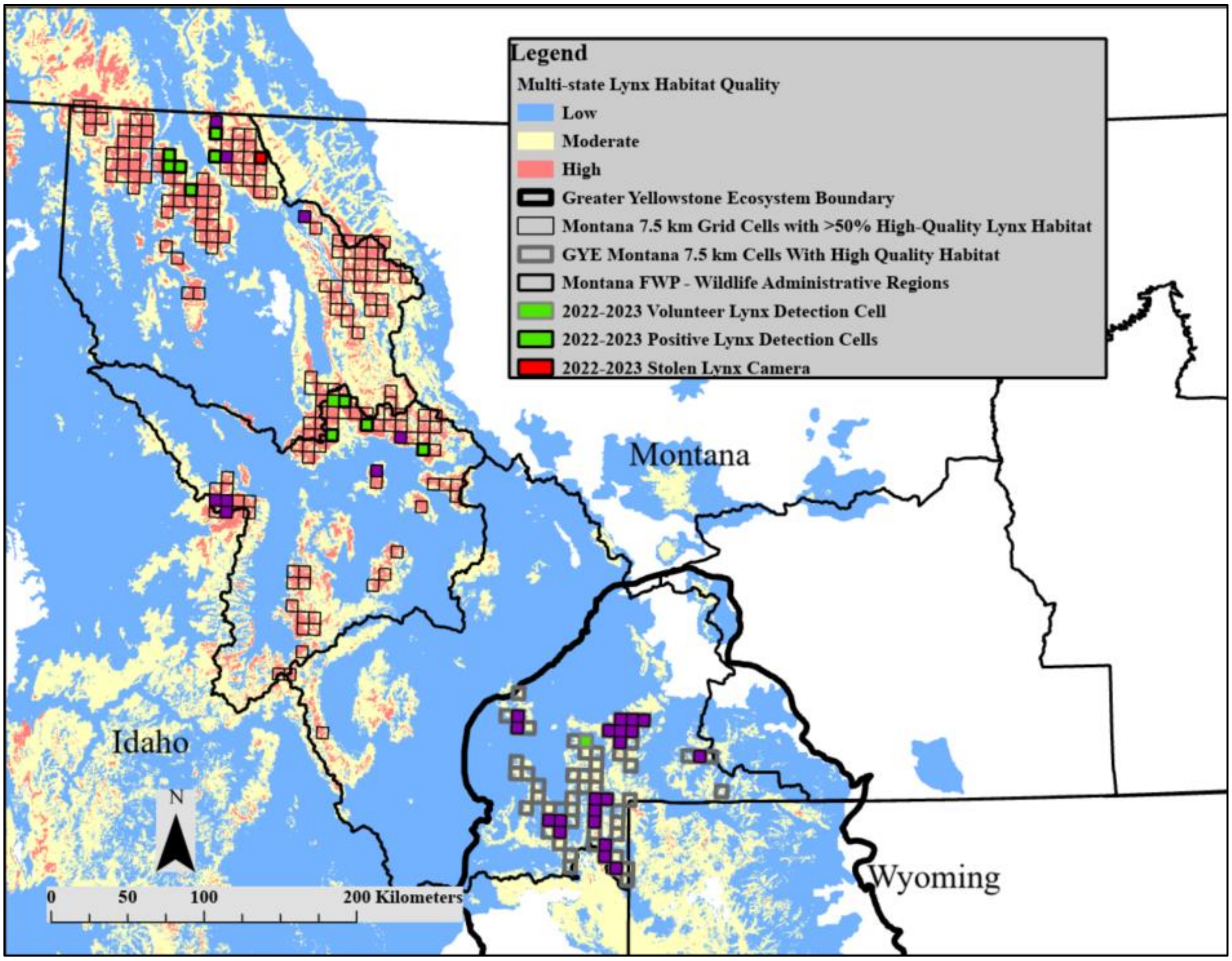

Figure 5. Lynx monitoring cells (7.5-km x 7.5-km) sampled in Montana, USA, from 1 December 2022–30 April 2023 including 10 cells with positive lynx detections from survey efforts, 1 cell with a positive detection from a volunteer camera, and one stolen camera.

Occupancy was markedly higher in the core habitat study area compared to the GYE study area. According to the site-specific model, the occupancy rate in the core habitat study area (psi = 0.77, SE = 0.17), whereas the occupancy rate in the GYE study area was functionally 0 (psi = $6.0e10^{-5}$, SE = $2.0e10^{-3}$). On average the cells sampled in the core habitat study area were comprised of 77% high-quality habitat, whereas cells in the GYE study area were 12% high quality habitat. If we use the habitat model to estimate the occupancy for cells with the average proportion of high-quality habitat, the habitat model estimates occupancy at 0.01 (SE = 0.03) for the GYE study area and 0.87 (SE = 0.33) for the core habitat study area. Occupancy increased in concert with the proportion of high-quality habitat in a cell (Figure 4). Occupancy ranged from 0.99 (SE = 0.07) when 100% of the cell was classified as high-quality habitat to $3.8e10^{-3}$ (SE = 0.01) when there was no high-quality habitat in a cell.

Though occupancy estimates varied among the models, the detection estimates were similar. The habitat model had the lowest detection rate estimate of 0.27 (SE = 0.10), with a cumulative detection rate of 0.79 for the 5 sampling occasions. The constant model had the greatest detection estimate of 0.298 (SE = 0.077) but the site-specific model detection estimate was almost identical, (0.295; SE = 0.077).

Power analysis – Objective 4

We used the results from occupancy models to conduct simulations to evaluate our ability to detect changes in lynx occupancy over time. We used the most conservative detection estimate (p = 0.27; 95% CI 0.13–0.45) from the habitat model to estimate the probability of occupancy after 5 sampling occasions of no detections, which was affected by the occupancy rate of the sites (Figure 5). The probability that any site was occupied (psi = 0.37) after 5 months of no detections was 0.11. The lower 95% confidence interval estimate for detection (p = 0.13) increased the probability that a site was occupied (psi = 0.23), while the upper confidence interval estimates for detection (p = 0.45) decreased the probability site was occupied (psi = 0.03). When we used the site-based occupancy rates, these estimates changed. The core habitat study area had a 0.41 probability of an occupied site after no detections (psi = 0.63–0.14 using the lower and upper detection estimates, respectively). The GYE study area had a $1.3e10^{-5}$ (essentially 0) probability of an occupied site after no detections (psi = $3.0e10^{-5}$–$3.0e10^{-6}$ using the lower and upper detection estimates, respectively).

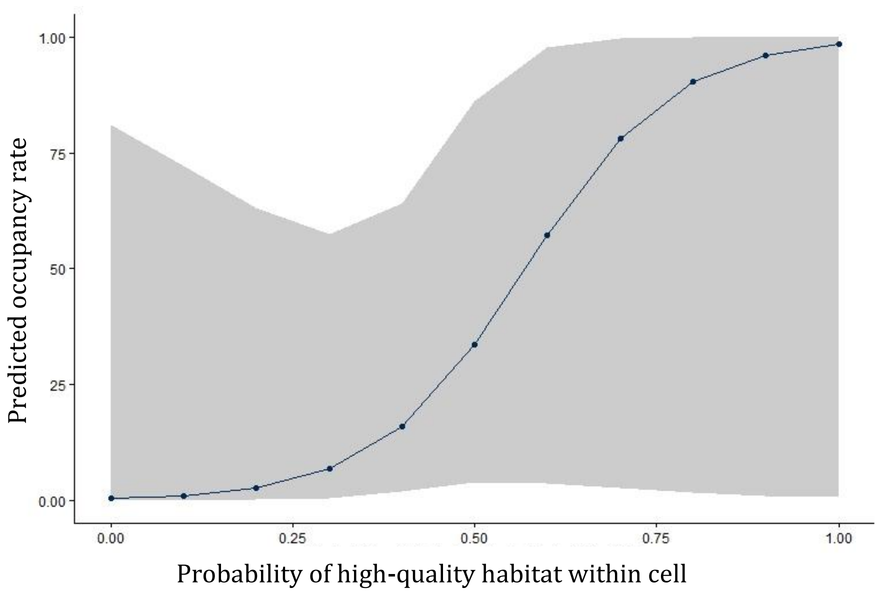

Figure 4. The estimated relationship between the proportion of high-quality lynx habitat within the sampled grid cell and the predicted occupancy rate from the lynx 2022–2023 monitoring season in Montana, USA. The shaded gray area represents the 95% credible interval.

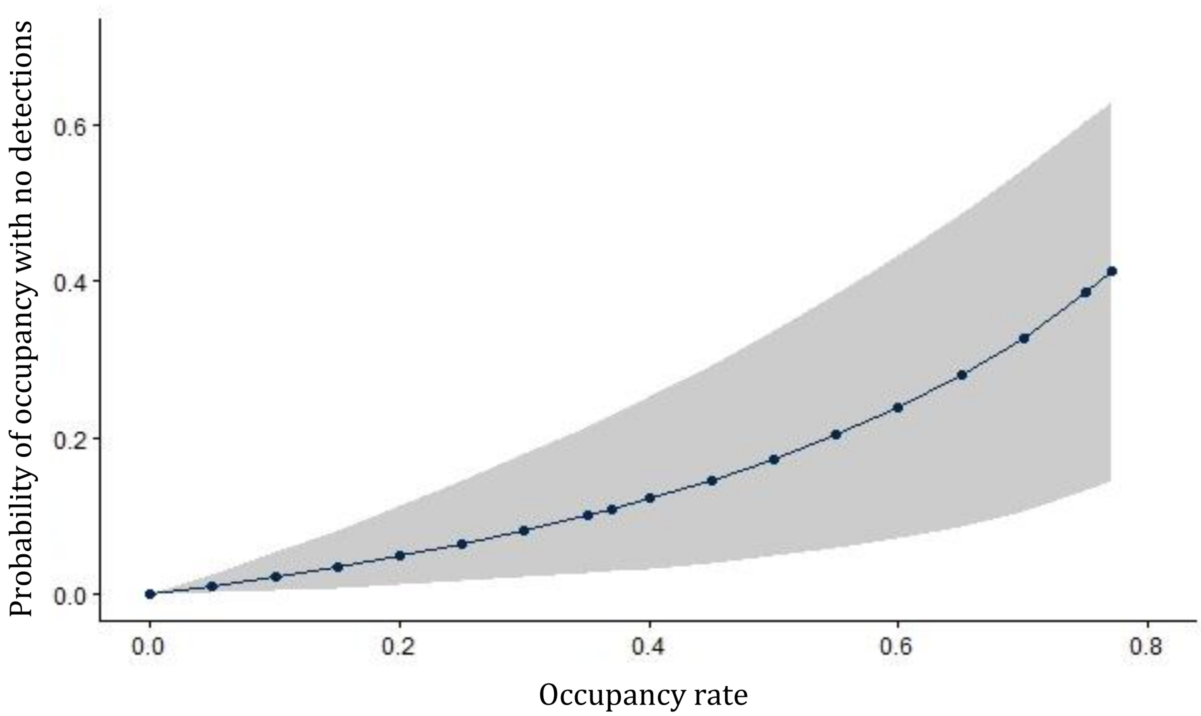

Figure 5. The probability of a site being occupied in Montana, USA, after 5, 30-day sampling occasions (1 December 2022–29 April 2023) without a lynx detected based off the lowest detection estimate from the habitat occupancy model (0.27; 95% confidence interval 0.13–0.45). The shaded gray area represents the 95% confidence interval.

Based on this power analysis, we estimate that the study design for the 2023–2024 lynx monitoring effort (sampling 90 cells in core habitat) should have a 99% probability (95% confidence interval 0.61–1.00) of detecting a 50% decline in lynx occupancy. This was determined from the estimated occupancy for the core areas during the 2022–2023 study period (0.77) to a simulated occupancy of 0.38 over a 5-year period. Concurrently, this sampling rate should have a 60% probability (95% confidence interval 0.41–0.99) of detecting a 35% decline in occupancy over the same time frame (a new occupancy rate of 0.50). The smallest simulated detectable change in occupancy with a power of 0.80 is a new occupancy rate of 0.44 (power = 0.81, 95% confidence interval 0.35–0.99; Figure 7). This analysis also showed that sampling 45 cells in core lynx habitat over 5, 30-day sampling occasions would result in a power of 0.87 to detect a 50% decline in occupancy. If the detection rate was 0.13 (the lower 95% confidence interval), power was reduced to 0.43 (Figure 6).

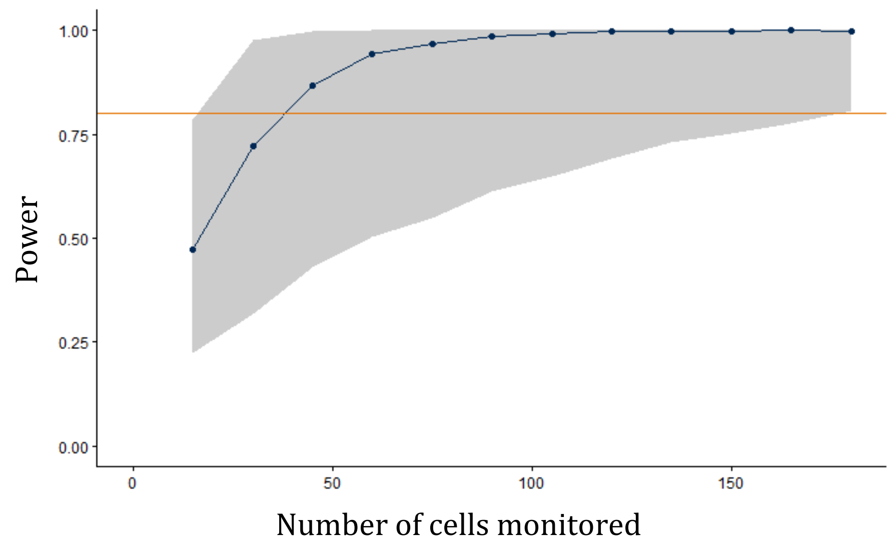

Figure 6. Occupancy simulation results showing the power of the experiment to detect a difference between a null occupancy of 0.77 (the estimated occupancy for core area during the 2022–2023 study period) and a simulated occupancy of 0.38 (a 50% decline in occupancy). Each point represents the estimated power of 100,000 simulations of the experiment when alpha (0.05) and the number of sampling occasions (5 occasions) were held constant. The shaded gray area represents the 95% credible interval, and the orange line represents a power of 0.8.

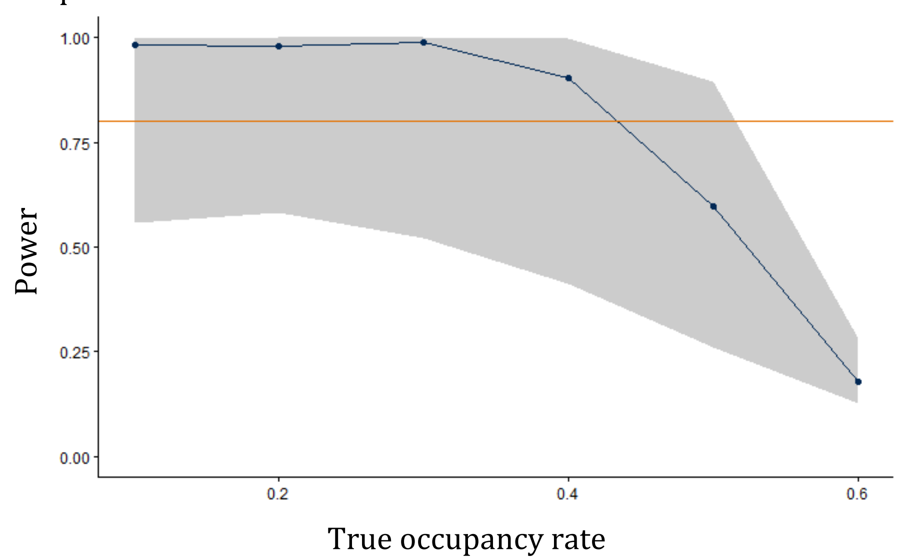

Figure 7. Occupancy simulation results showing the power of the experiment to detect a difference between a null occupancy of 0.77 (the estimated occupancy for core areas during the 2022–2023 study period) and a simulated true occupancy rate. Each point represents the estimated power of 100,000 simulations of the experiment. The sample size was held at 90 cameras for 5 encounter occasions and alpha was held constant at 0.05. The shaded gray area represents the 95% credible interval, and the orange line represents a power of 0.8.

Discussion

The results from this pilot study verified that our sampling framework and survey method can reliably detect lynx in core habitat areas in Montana. The use of scent dispensers and the visual attractant of a CD near roads and trails in high-quality habitat over a 5-month period resulted in a cumulative detection rate of 0.79. Detection rates were highest during the lynx breeding season (31 March–29 April) when lynx frequently travel greater distances, increasing the probability that they will encounter a monitoring station (Crowley et al. 2013). Our high detection rate supports the efficacy of our field methods to detect lynx, and the timing of increased detections emphasizes the need to monitor through April.

Our estimated occupancy in core habitat was higher than expected (psi = 0.77) compared to previous estimates of lynx occupancy in Colorado (psi = 0.45; p = 0.45; J. Ivan, Colorado Parks and Wildlife [CPW], personal communication). This higher occupancy is most likely a result of Montana having a well-established population of lynx compared to Colorado's reintroduced population. Methods that CPW used included 4 cameras within each cell which may have bolstered their detection rates compared to our use of 1 camera per cell.

We did not detect lynx in the GYE study area, which has been previously acknowledged as unsupportive of a breeding population of lynx (USFWS 2023). However, we did have one report of a positive lynx detection in the moonlight basin area of the GYE study area during the study period. It is unknown if this individual was resident or transient to the area. Regardless it is unlikely that the habitat in this area could support long-term lynx occupancy or a breeding population (USFWS 2023). The lack of detections in the GYE reaffirms that the focus of lynx monitoring in Montana should be on state's largest blocks of high-quality lynx habitat that support continued occupancy. Lynx populations naturally fluctuate within marginal habitats in Montana (Slough and Mowat 1996) and monitoring these fluctuations would add a tremendous amount of "noise" to population trends which was seen in our constant model compared to our study area model. In fact, monitoring areas where natural fluctuation is expected would reduce the ability to detect a population change from within the core areas where long-term persistence can be expected (Ruiz-Gutierrez and Zipkin 2011). While true status of the population in the state might be more accurately represented by monitoring all areas of lynx habitat, the expense would be far greater. It is widely accepted that those natural fluctuations include absence or near absence from areas where habitat quality is moderate or poor in Montana (Squires et al. 2013).

This pilot study provided information to inform statewide monitoring of core areas for lynx. The resulting power analyses revealed that our current study design has a greater ability detect a much smaller change (35% change rather than 50% change) in occupancy by sampling 90 of the 180 cells in core lynx habitat in Montana. These results and those to come in our future lynx occupancy work (2023–2024) will help inform decisions during the reassessment of lynx critical habitat by the Service and the finalization of the lynx recovery plan in 2024.

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Future Work

In 2023–2024, FWP embarked on a multi-state, lynx monitoring project in collaboration with Idaho and Wyoming. One hundred twenty-five core habitat cells will be sampled across all 3 states (Figure 9; 90 in Montana, 23 in Wyoming, and 12 cells in Idaho). Stations will be recovered in spring and summer of 2024 with results from this effort expected in 2025. This work, along with the findings from the pilot study, will form a baseline of lynx occurrence (probability of occupancy) across much of the western U.S. from which to evaluate future changes in occupancy that might be due to influences of conservation action, environmental and food-based change, or anthropogenic disturbance.

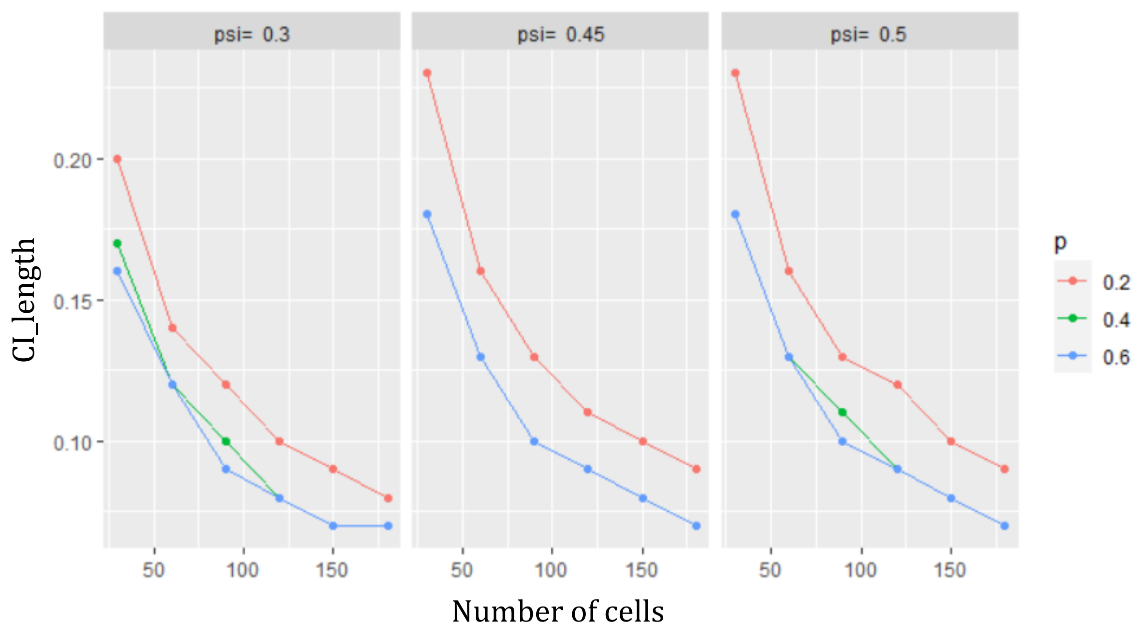

Figure 8. Power analysis results displaying expected 95% confidence intervals as a function of sample size for lynx occupancy estimates given reasonable expectations for occupancy rate (psi), detection rate (p).

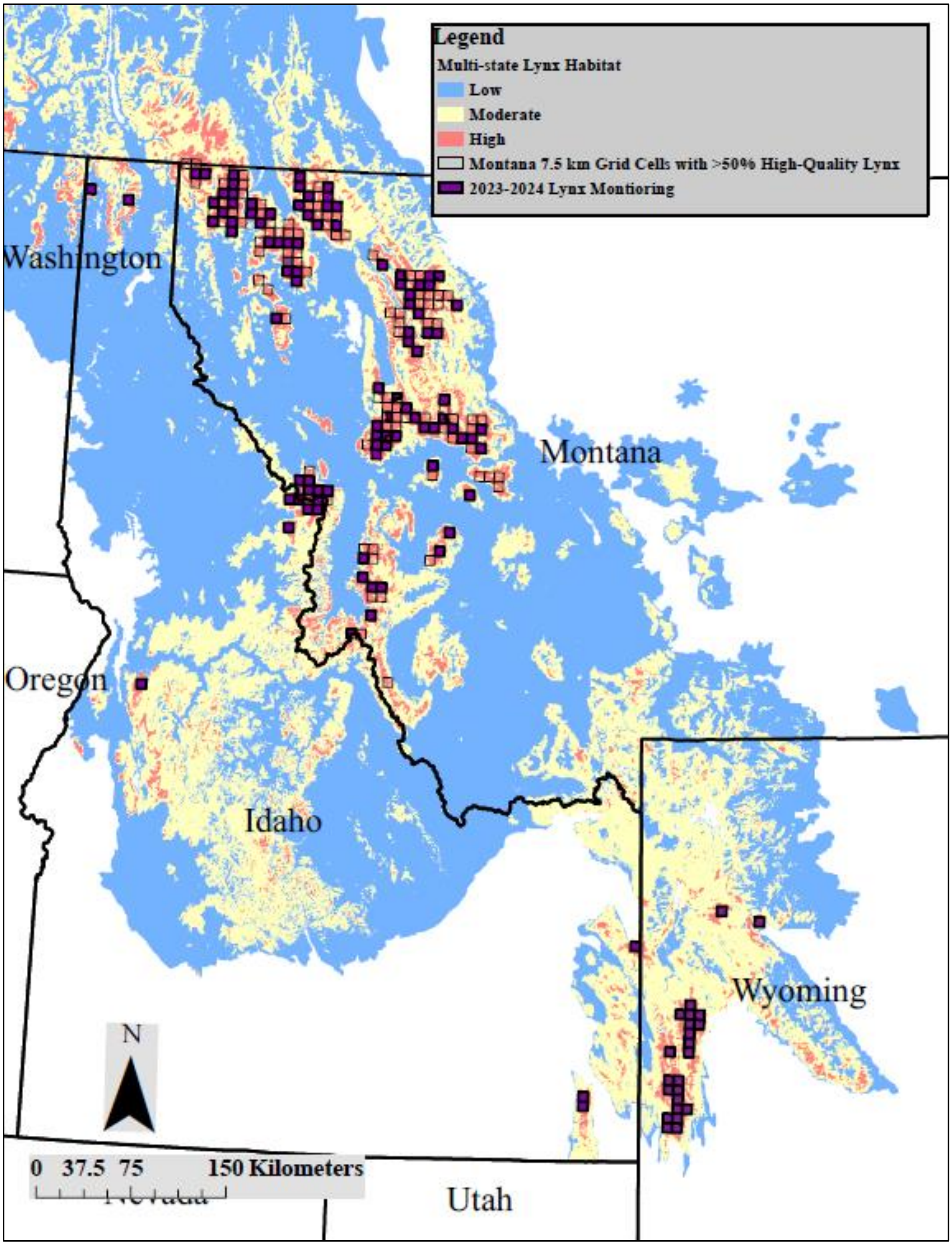

Figure 9. Lynx monitoring cells (7.5-km x 7.5-km) that contain >50% high-quality lynx habitat and those to be sampled for lynx occupancy survey from 1 December 2023–31 March 2024 in Idaho, Montana, and Wyoming, USA.

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