MONITORING SPRUCE GROUSE IN MINNESOTA: SURVEY DEVELOPMENT (2014–2017)

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SUMMARY OF FINDINGS

Data collection began in 2014 to develop survey methodology for a large-scale survey of spruce grouse (*Falcipennis canadensis*) in Minnesota. During 2014 and 2015, we examined 2 primary methods of spruce grouse detection: a cantus-call survey and a fecal pellet survey. Based on field work conducted in 2014 and 2015, we determined that pellet surveys had 3-5 times the apparent detection rate of call surveys (20% and 4%, respectively). During 2015, pellet and call surveys at paired points on and off roads allowed examination of the effects of roads on survey counts. These paired surveys indicated that detections at road-based points were lower than at points located off roads at 1 of 2 study areas, but this effect was minimal in forest types preferred by spruce grouse. In 2016, we piloted a road-based pellet survey throughout the probable spruce grouse range in Minnesota. Results were consistent with anecdotal accounts of spruce grouse observations from wildlife managers and indicated that spruce grouse are relatively rare in the Northern Minnesota Drift and Lake Plains Ecological Classification System (ECS) section and more abundant in the Northern Superior Uplands and Northern Minnesota and Ontario Peatlands sections, with relative abundance increasing along a southwest to northeast gradient. We conducted simulations to examine our ability to detect meaningful changes in the population (>15% decline over 10 years) and concluded that the pellet survey could accomplish this goal. In 2017, we visited 1,426 potential survey points (85% of the potential sampling frame) to determine which points were suitable for the operational survey. We were able to eliminate 266 points due to inaccessibility (e.g., the presence of wetlands, ditches, steep topography, private land ownership) or unsuitable habitat (e.g., recent harvest, blowdown, or fires). Our findings will inform the selection of the set of points to be included in the annual operational survey, which we plan to initiate in 2018. Upcoming work will identify survey routes (clusters of points) and training cooperators so that surveys are conducted similarly across the survey region.

INTRODUCTION

The spruce grouse is considered a Species of Special Concern in Michigan (Michigan DNR 2005) and was listed as threatened in Wisconsin in 1997 (Wisconsin DNR 2004). Minnesota is unique among the Lake States in having a sizeable spruce grouse population that still permits spruce grouse hunting. Yet, the only data the Minnesota Department of Natural Resources (MNDNR) collects on spruce grouse is estimated total harvest as part of the annual MNDNR small game mail survey (Dexter 2016). Estimated total harvest has been 10,000–27,000 birds/year over the last 10 years (Dexter 2016). However, spruce grouse harvest may be more reflective of ruffed grouse hunter numbers than spruce grouse numbers; thus these data cannot be used as a population index (Gregg et al. 2004). The MNDNR mail survey also provides some information on geographic distribution via a “county hunted most” question, but it is probably insufficient for monitoring anything less than large-scale range changes. Hence, the

MNDNR has limited data on spruce grouse distribution, abundance, and population trends in Minnesota despite a responsibility to manage spruce grouse during a period of expected habitat loss due to climate change (see Roy et al. 2013a). Thus, there is a need for better population-monitoring data for spruce grouse in Minnesota.

Developing large-scale monitoring programs that are both reliable and cost effective is challenging, especially when the species is relatively rare and occupies habitats that are not easily accessible. New York (Fritz 1979) and Wisconsin (Worland et al. 2009) have conducted statewide surveys of spruce grouse. Wisconsin used a spatially balanced stratified sampling design with 4 stand size classes (range: 8.1–1,242 ha), in which they surveyed multiple points in 81 forested wetlands during 3 visits. In New York, 67 habitat patches were surveyed during 220 visits. However, these surveys were only conducted during a few years, were labor intensive, and were not designed to be long-term monitoring projects. Any long-term, large-scale monitoring effort of spruce grouse in Minnesota would need to be easy to execute, repeatable, and representative of spruce grouse populations. Logistical, financial, and resource constraints often limit survey-design options for large-scale monitoring efforts. In this case, spruce grouse occupy habitats that are very difficult to access away from roads. A roadside survey would possess the logistical ease desirable for a statewide effort, but several potential biases would need to be addressed.

As part of a pilot study, we evaluated survey methods that might be useful for monitoring spruce grouse populations in Minnesota. We evaluated an auditory survey using playback of female cantus calls, which is the most common approach to survey spruce grouse (Fritz 1979, Boag and McKinnon 1982, Whitcomb et al. 1996, Lycke et al. 2011, among others). We also conducted pellet surveys and used pointing dogs to locate birds on survey plots following completion of a cantus-call survey (Roy et al. 2013b, 2014).

OBJECTIVE

1. Assess the feasibility of using a roadside survey to determine the distribution and population trends of spruce grouse in Minnesota.

2. Design and implement an annual roadside survey in 2018.

STUDY AREAS

In 2014, we focused on the Red Lake Wildlife Management Area (RLWMA) and Beltrami Island State Forest (BISF; Roy et al. 2013b, 2014). This study area is on the southwestern edge of the presumed spruce grouse range, where changes (range contraction or negative trends in abundance, density, or patch occupancy) might occur earlier than in more central portions of the range. In 2015, we focused on portions of RLWMA and BISF where spruce grouse detections occurred in 2014, so survey methods would be evaluated in areas where birds were known to occur (Figure 1). We also added a second study site near Isabella (Figure 2), which is more centrally located within Minnesota spruce grouse range. This study site offered insights into survey methods where populations might be more robust to initial habitat changes. Hereafter, we refer to this study site as the NE study site and the one at RLWMA and BISF as the NW study site.

In 2016 and 2017, we expanded the survey area to include all or most of spruce grouse range in Minnesota (Figure 3 and 4). The current limits of spruce grouse range are unknown, so we focused on forest types used by spruce grouse within 3 ECS sections (Northern Minnesota and Ontario Peatlands, Northern Superior Uplands, and Northern Minnesota Drift and Lake Plains) to delineate an area to be surveyed for spruce grouse. We also referenced harvest data reported in the Small Game Hunter Mail Survey (Dexter 2015) to incorporate county-level harvest information for spruce grouse.

METHODS

Identifying Spruce Grouse Habitat

The literature is conflicting with respect to forest ages of importance for spruce grouse; earlier successional stages have been reported to be important in the western U.S. (Boag and Schroeder 1992), but mature forest was important in Wisconsin (Anich et al. 2013). In 2014, we included forest types reported to be preferred by spruce grouse in our region, including jack pine (*Pinus backsiana*), black spruce (*Picea mariana*), and tamarack (*Larix lariana;* Robinson 1969, Pietz and Tester 1982, Anich et al. 2013). We included all stand ages because of the lack of clarity in the literature but focused on preferred habitat types rather than all used habitat types. We also included white cedar (*Thuja occidentalis*), which was reported to be used but not a preferred habitat type (Anich et al. 2013), because managers were specifically interested in surveying this forest type.

In 2015, we added balsam fir (*Abies balsamea*) and red pine (*Pinus resinosa*) forest types to our survey. This decision was based on 2014 detections in stands with these species components that exceeded our expectation of use based on their representation in the sample. We also added white spruce (*Picea glauca*) because it was reported as used but not preferred in the literature, and inclusion of these other used but not preferred stand types seemed to warrant its inclusion for consistency. We used Forest Stand Inventory (FIM) data on state managed lands administered by the MNDNR at both the NW and NE study sites to identify survey points based on forest stand types and age. Field Sampled Vegetation (FSVeg) spatial data was also used on lands managed by the U.S. Forest Service Superior National Forest at the NE site to identify survey points in the appropriate forest stand types. We excluded stand ages listed as "under development" (i.e., 0–5 years) in the FIM data to exclude areas that might not have established as forest. Timber harvest data (US Forest Service 2015a), Motor Vehicle Use Maps (U.S. Forest Service 2015b), and fire records (National Interagency Fire Center 2013) were also used for the NE study site to exclude stands that were recently harvested or burned and to identify roads suitable for survey routes.

In 2016 and 2017, we continued to use forest types used in 2015 (black spruce, jack pine, balsam fir, red pine, white spruce, tamarack and white cedar $\geq$6 years old) and we expanded our forest-inventory data to include lands administered by the U.S. Forest Service Chippewa National Forest as well as by county land departments, including Aitkin, Beltrami, Carlton, Cass, Clearwater, Crow Wing, Hubbard, Itasca, Koochiching, Lake, and St. Louis Counties. Since harvest and stand replacement disturbance information was not readily available for all forest-inventory sources, a satellite-interpreted forest loss data layer (Hansen et al. 2013) was used to identify areas of forest stands $\geq$6 years old. Forest stands meeting the cover type and age requirements were further dissolved into patches to determine sites that had a sufficient amount of habitat to support spruce grouse. Habitat patches $\geq$8 ha (Fritz 1979, Whitcomb et al. 1996) that overlapped accessible roads were used to identify potential stands to survey.

Survey Points and Routes

In 2014, we used Geographic Information Systems (GIS) road layers (Minnesota Department of Transportation and MNDNR) to identify roadways that were within 40 m of potential habitat polygons (jack pine, black spruce, tamarack and white cedar; see above). We then classified roadways as primary or secondary based on their accessibility during the April–May survey period (e.g., plowed vs. not plowed). We established survey points on road segments that bisected or were within 40 m of habitat polygons. Points were spaced $\geq$300 m apart to ensure independence among points based on estimates that playback calls can be heard 100–150 m from the speaker (Schroeder and Boag 1989; Lycke et al. 2011; Anich unpubl. data). Road segments and associated survey points were then grouped into survey routes based on logistical considerations.

In 2015, we used the same GIS layers to select survey points, but also used current data for U.S. Forest Service roads, forest harvest, and fire data for the NE study site (U.S. Forest Service 2013, National Interagency Fire Center 2013, U.S. Forest Service 2015a,b). However, our focus in the second season was a comparison of off-road and on-road survey points to examine the impact of roads on survey detections. We selected paired points that had at least 30% spruce grouse habitat (based on selected forest types) within 150 m of each point, but limited our selection to areas where habitat occurred on both sides of the road. Off- and on-road points were separated by 300 m, and we alternated the side of the road where off-road points were selected, except when creeks limited access on foot.

In 2016 and 2017, we used a GIS to identify 1,862 and 1,686 potential survey points, respectively, which were in probable spruce grouse range, located on accessible roads, permitted access off road without limitations by water barriers, had ≥30% spruce grouse habitat within 150 m of each point on both sides of the road, and were associated with spruce grouse habitat patches ≥8 ha. In 2017, we eliminated nearly 200 points after review of air photos indicated that they obviously lacked the habitat and access requirements that were otherwise selected through analysis of the available forest inventory, roads, and hydrography data. We spaced points ≥400 m to obtain the greatest spatial coverage of focal stands throughout the probable spruce grouse range. In 2017, we manually added points that met survey criteria on tribal lands owned by the White Earth Nation, Red Lake Band of Chippewa, Leech Lake Reservation, Fond Du Lac Band and Grand Portage Band of Lake Superior Chippewa, and 1854 Treaty Authority. In 2016, we used a Generalized Random Tessellation Stratified Sampling approach (Stevens and Olsen 2004) to select seed points for approximately 80 routes and attempted to identify groups of 8–10 points that were in spatial proximity to construct survey routes. We also considered proximity to potential lodging centers (travel time), local expertise on accessibility, and the distribution of routes by ECS subsections and sections when selecting the final sample of routes and points. Our final sample in 2016 consisted of 65 routes with 2–13 survey points/route (median = 10). Forty-three routes (400 survey points) were located in the N. Superior Uplands (core of probable spruce grouse range in MN), 11 routes (120 points) were in the N. Minnesota & Ontario Peatlands (containing the RLWMA and BISF), and 11 routes (93 points) were in the N. Minnesota Drift & Lake Plains (southern edge of probable spruce grouse range in MN). In 2017, we did not cluster points into routes, but rather attempted to scout all possible points that would be suitable for inclusion in an annual survey.

Cantus Call Surveys

We used a playback of female cantus calls to conduct point-count surveys of spruce grouse (Fritz 1979, Boag and McKinnon 1982, Schroeder and Boag 1989, Whitcomb et al. 1996, Lycke et al. 2011). In 2014, we surveyed as many points as possible to provide information on survey duration (1–15 min), time needed to complete multiple surveys, habitat associations, and the responsiveness of spruce grouse to cantus calls (i.e., time of day and season). Surveys were conducted during April–May, beginning at sunrise, when winds were <10 mph and precipitation was absent or light. Each point count lasted 15 min (Lycke et al. 2011, Anich et al. unpubl. data) and was divided into 5 consecutive 3-min listening intervals. The 8-sec cantus call was broadcast once per min throughout the 15-min listening period. Observers recorded initial and subsequent detections of each spruce grouse by listening interval, which allowed us to construct individual detection histories for a time-of-detection analysis (TOD, Alldredge et al. 2007). We also recorded type of initial detection (flutter flight, approach, etc.), survey date, arrival time, wind speed, temperature, dominant tree species (as classified from the roadway: jack pine, black spruce,tamarack, white cedar, red and white pine, balsam fir, deciduous, other), and background noise (none, low, medium, high).

In 2015, we modified call-survey methods to incorporate findings from 2014. Specifically, we reduced the survey length from 15 to 9 min, began surveys 30 min earlier, and ended call surveys by 0930 hr. For analysis, we used a dynamic occupancy modeling approach (MacKenzie et al. 2006:183–224) to look at TOD and revisits in the same analysis. We used the ‘colext’ function in the R package ‘unmarked’ (Fiske and Chandler 2011, R Core Team 2016) to fit models. We used visits as the primary sampling unit and TOD as secondary sampling occasions, and we allowed the true occupancy status to change between visits (i.e., via transition probabilities). We examined 4 site-level covariates (study area, year, location [road vs. off-road], forest type), 5 visit-level covariates (observer, survey date, start time, start temperature, and wind speed), and 2 observation-level covariates (TOD interval and previous detection).

Call surveys were discontinued in 2016. Data collected in 2014 and 2015 indicated that pellet surveys had substantially higher detection probabilities and would be easier to implement in a large-scale survey of spruce grouse in northern Minnesota

Pellet Surveys

We counted grouse pellets and roost piles <1 m on either side of transects. We distinguished ruffed grouse pellets from spruce grouse pellets on the basis of length, thickness, uric acid wash, and color (N. Anich, A. Ross, M. Schroeder, pers. comm.). Ruffed grouse pellets tend to be shorter, thicker, and usually have a uric acid wash, whereas spruce grouse pellets are longer, thinner, and infrequently have a uric acid wash. Spruce grouse pellets are also darker green in color when spruce grouse are consuming conifer needles (during winter), but color changes depending on diet (personal observation); spruce grouse pellets can have a similar color to ruffed grouse pellets later in the spring. Finally, we recorded dominant and subdominant tree species along each circular path to compare forest-type classification based on GIS, roadside observations, and pellet surveys.

In 2014, we surveyed circular transects of 75-m and 100-m radii centered on call survey points on roads. In 2015, we surveyed circular transects of 100-m radius centered on paired points on and off roads, because the larger radius improved detection. Surveys were repeated up to 3 times to allow for modeling of detection using function ‘occu’ in R package ‘unmarked’ (Fiske and Chandler 2011). In 2016, pellet surveys were conducted at each transect once to maximize spatial coverage, and all pellet transects were centered on roads.

In 2016, we fit generalized linear mixed-effect models to the data to compute 2 monitoring metrics: an occupancy index (using presence-absence of pellets and a binomial link function) and a pellet-count index (using a Poisson link function). In each case we treated ‘route’ as a random effect to account for the clustered sampling design, and evaluated potential covariates affecting the response metric (e.g., amount of spruce grouse habitat, spatial location) as well as covariates that might serve as a surrogate for probability of detection (i.e., snow coverage [none, partial, complete] and days since last snow; based on results from 2014 and 2015). We used the function ‘glmer’ in the R package ‘lme4’ (Bates et al. 2015, R Core Team 2016) to fit the models, and we used AIC to select among competing models. Because our sample of points was not proportionally allocated (we sampled more heavily in core areas), we used our best approximating models, with the surrogate variable for detection held constant, to predict mean naïve occupancy and pellet abundance for each point in the sampling frame (1,862 points). We then computed a simple arithmetic mean prediction by ECS section and rangewide to generate 2 monitoring metrics. We used a bootstrap of routes (200–300 replicates, with replacement) to compute percentile confidence intervals that included uncertainty in model-fitting and prediction. We also used the R package ‘akima’ (Akima and Gebhardt 2015) to implement a bivariate interpolation of our irregularly spaced prediction surface, which we used to qualitatively assess how model predictions varied over Minnesota’s probable spruce grouse range as a function of spatial location and the relative abundance of jack pine and black spruce cover type.

Lastly, we used a Monte Carlo simulation with 200 replicates to evaluate whether the proposed sampling effort was adequate to detect a true decrease in a simulated population over a 10-yr monitoring interval, where the decrease was manifested by a decreasing trend in probability of site use. We allowed the decrease in mean probability of use to vary by ecoregion ($\lambda = 0.935$ annual decline in the southern part of the range and smaller decreases elsewhere, $\lambda = 0.984$ and 0.972, corresponding to 10-year declines of 49%, 15%, and 25%, respectively) and included small-to-moderate amounts of random variation that reflected annual variability (process variation), geographic variability, and binomial variation in the state (probability of use) and observation (probability of detection) processes. We used pilot-study results to inform starting parameter values and sampling and process variation in a Monte Carlo simulation. We used a generalized mixed-effects model to estimate a trend (in our index of use) for each simulated population and then evaluated the distribution of the estimated trends and the proportion of estimated trends that were negative (a qualitative power analysis).

In 2017, we attempted to refine our detection covariates by conducting pellet surveys at 76 points, of which 74 had been surveyed in 2016. We documented the time since last snow fall and rated the survey conditions on a scale of 0-10, with 0 being the poorest and 10 indicating optimal survey conditions. We used 0 to indicate that recent snowfall covered all but the freshest pellets, and 10 to indicate a strong contrast against pellets created by a dissipating snow pack, with 100% ground coverage by snow received >10 days prior. We also noted whether pellets were found on snow or on bare ground and documented how much of each transect (to the nearest 5%) was in a forest type identified as being used by spruce grouse.

We also scouted 1,426 potential survey points (85% of the potential sampling frame) to help determine the appropriateness of a point for inclusion in an annual pellet survey based on a coarse assessment of site-level vegetation structural density (i.e., open/closed), forest maturity (i.e., early/mature), and the absence of wetlands, ditches, steep topography, private property, or recent timber disturbance. The remainder of points could not be scouted due to impassable roads during the scouting period.

RESULTS

2014 Abridged

We detected spruce grouse at 26 (4%) of 530 call-survey points. Birds were detected in all 5 listening intervals, although 78% of birds were detected in the first 3 intervals. Our best approximating hierarchical occupancy model included detection covariates for survey date, arrival time, whether the bird was detected in a previous listening interval, and an occupancy covariate describing the relative amount of spruce grouse habitat surrounding the listening point (habitat sides = 0, 1, 2). Mean probability of detection was negatively associated with survey date and arrival time (Figures 5 and 6). Not surprisingly, probability of detection increased dramatically if a bird was detected in a previous listening interval. The mean probability of occupancy for a listening stop with spruce grouse habitat on both sides of the road was 0.23 (95% CI = 0.02–0.78; Figure 7), and the overall probability of detection for the entire 15-min survey, given mean covariate values for survey date and arrival time, was 0.25 (95% CI = 0.02–0.93).

We conducted pellet surveys at 230 listening points and detected pellets at 45 (20%) points. Pellet surveys and cantus-call surveys had 82% concordance for presence-absence of spruce grouse.

However, we detected pellets at 36 points (16%) where we failed to detect a bird during cantus-call surveys. This contrasts with failure to detect pellets at 5 (2%) points where we detected spruce grouse during cantus-call surveys. The 100-m radius survey path resulted in 28 detections (39%) compared to 18 (11%) detections with a 75-m radius path. Nineteen additional spruce grouse were located while walking transects around survey points with dogs.

2015 Abridged

We surveyed 200 paired points in the NW study area and 190 points in the NE study area 1–3 times. Our findings for the cantus call survey in 2015 were qualitatively similar to those in 2014, with higher detection probabilities earlier in the day, earlier in the season, earlier in the listening period or in a former listening period (Figures 5–6). The call detection rate was 3-fold higher (compared to 2014), but still 3–4 times lower than that for pellet surveys. Comparisons between study areas indicated similar detection rates with the call survey and pellet survey on road-based points, but slightly higher detection rates at off-road points in the NE study area (Table 1). However, this effect was much smaller in stands that are preferred by spruce grouse based on the literature (Figure 8). Based on these findings, a pellet survey was deemed the better approach for a large-scale survey.

2016

Our final sample consisted of 567 survey points organized into 65 survey routes. However, 77 (14%) of the 567 survey points would probably need to be removed or replaced in an operational survey due to significant access challenges (e.g., water crossings, long walks, difficult terrain, etc.). Eighty-two percent of the points were located on dirt roads and traffic was light to none during most (86%) surveys. Based on GIS data, spruce grouse habitat at the 567 survey points comprised, on average, 80% of the cover, with jack pine and black spruce cover types accounting for 38% (range = 0–100%). Upon inspection, 8 plots (1%) were dominated by deciduous or open cover types, but they contained at least some marginal spruce grouse habitat on 1 side of the road (habitat = 1). Fifty-two percent of the points contained $\geq$30% jack pine or black spruce cover types. Thus, the GIS data performed reasonably well in identifying potential survey points.

Spruce grouse pellets were detected at 24% of the survey points, but it varied by ECS section (Table 2). On points where spruce grouse pellets were detected, we counted a mean of 5.3 pellet groups (SD = 6.2); 87% of these points contained roost piles and 24% contained fresh pellets (Table 3). Ruffed grouse pellets were detected at 56% of the survey points where spruce grouse pellets were detected. Unknown pellets (could not be confidently assigned to a species) were detected on 8% of “occupied” points but only 2% of “unoccupied” points.

The probability of detecting spruce grouse pellets was positively correlated with percent cover of jack pine and black spruce habitat (based on GIS data), negatively correlated with complete snow cover (a surrogate for detection probability), and positively correlated with a southwest to northeast spatial gradient (Figure 9). The same model structure best explained variation in pellet-group counts, but uncertainty associated with the mean functions was much greater (e.g., Figure 10). Consistent with anecdotal information, both monitoring metrics suggested spruce grouse were relatively rare in the N. Minnesota Drift & Lake Plains eco-section and more abundant in the Northern Superior Uplands and N. Minnesota & Ontario Peatlands eco-sections (Figure 11). Likewise, when viewed over a smoothed prediction surface, both metrics suggested the relative abundance of spruce grouse increased on a southwest to northeast gradient (Figure 12).

2017

Based on site visits in 2017, we eliminated 266 (19%) survey points from the sampling frame due to wetlands (n = 76), ditches (n = 57), steep topography (n = 58), recent or impending timber harvest (n = 64), private landownership (n = 7), and other reasons such as recent fires or blowdowns (n = 64). We could not scout 260 points because of impassable roads during our visits or time limitations resulting from unsafe travel conditions. Thus, the final sampling frame consisted of 1,160 potential roadside-survey points.

We were able to detect a true decrease in probability of use in $\geq$93% of simulations under the proposed sampling effort across all ECS sections examined. At the section level, we could detect a true decrease in 79% of simulations in the Northern Minnesota and Ontario Peatlands, 91% of simulations in the Northern Minnesota Drift and Lake Plains, and 93% of simulations in the Northern Superior Uplands (Table 4).

We detected spruce grouse pellets at 13 (17%) of 76 points, with more detections on bare ground (11, 14%) than snow covered ground (5, 7%). However, unlike previous years with near complete snow cover, in 2017 many points lacked snow cover (16 points; 21%), only 7 points (9%) had complete snow cover, and the remainder had partial snow cover.

DISCUSSION

We would like to launch an annual, range-wide spruce grouse survey beginning in spring 2018. We propose that this survey, like the ruffed grouse, sharp-tailed grouse, and greater prairie-chicken surveys, will be conducted by cooperating biologists in MNDNR, U.S. Forest Service, County governments, tribal entities, non-governmental agencies, universities, and community colleges. Our intent is for the survey to be completed annually by cooperators and staff to allow for detection of population trends and changes in distribution. During winter 2017-2018, we will visit with cooperators and staff at locations throughout spruce grouse range to train biologists and volunteers in spruce grouse pellet identification and survey methodology.

We should be able to detect large changes in the population of spruce grouse with this survey. Current predictions of climate change suggest that the impending impact on spruce grouse will be large. Johnson (2008) suggested that as long as variation in detectability is small compared to variation in population size, then indices can be useful for monitoring. The intention of the statewide survey is to provide an index of population size that can be used to estimate the trend over time. We also hope to be able to monitor changes in spruce grouse distribution with the survey data.

Ideally, this survey would be conducted as the snow pack is melting in late winter to increase contrast between pellets and snow and to facilitate detection of pellets. Snow cover may become less typical as a result of the warming winters expected with climate change. Surveys can be conducted earlier in the calendar year, if snow cover is lost earlier. However, snow cover is not required to complete the survey; pellets are also visible against the forest floor. We will track snow conditions so that we can incorporate snow cover in the detection function. Climate change will likely affect the optimal timing of many different wildlife surveys.

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Table 1. Naïve detection rates for spruce grouse using 2 survey methods in northern Minnesota during springs 2014 and 2015.

Year	Study area	Location[1]	Method[2]	n (total)	n (used)	Prop. with detection[3]	95% LCL[4]	95% UCL[5]
2014	RLWMA	R	Call	530	26	0.05	0.03	0.07
2014	RLWMA	R	Pellet	230	45	0.20	0.15	0.25
2015	RLWMA	R	Call	100	13	0.13	0.06	0.20
2015	RLWMA	OR	Call	100	19	0.19	0.11	0.27
2015	Ely	R	Call	95	13	0.14	0.07	0.21
2015	Ely	OR	Call	95	24	0.25	0.16	0.34
2015	RLWMA	R	Pellet	100	64	0.64	0.55	0.73
2015	RLWMA	OR	Pellet	100	63	0.63	0.53	0.73
2015	Ely	R	Pellet	95	59	0.62	0.52	0.72
2015	Ely	OR	Pellet	95	76	0.80	0.72	0.88
2015	RLWMA	R	P+Add	100	68	0.68	0.59	0.77
2015	RLWMA	OR	P+Add	100	67	0.67	0.58	0.76
2015	Ely	R	P+Add	95	60	0.63	0.53	0.73
2015	Ely	OR	P+Add	95	76	0.80	0.72	0.88
2015	RLWMA	R	C+P+Add	100	70	0.70	0.61	0.79
2015	RLWMA	OR	C+P+Add	100	69	0.69	0.60	0.78
2015	Ely	R	C+P+Add	95	62	0.65	0.55	0.75
2015	Ely	OR	C+P+Add	95	77	0.81	0.73	0.89

[1]Location of survey points: R = road, OR = off-road.
[2]Survey method: C or call = call survey, P or pellet = pellet survey,
Add = additional sightings of spruce grouse at survey points.
[3]Proportion of survey points where spruce grouse or spruce grouse sign were detected.
[4]95% lower confidence limit of proportion.
[5]95% upper confidence limit of proportion.

Table 2. Sample statistics and occurrence indices for a survey of spruce grouse pellets at points (pts) in northern Minnesota during spring 2016.

ECSS[1]	No. possible sample pts	Prop. sample	No. pts surveyed	Sample fraction	No. survey routes	Prop. pts pellets detected	Prob. pellets post-adjust[2]	85% LCL[3]	85% UCL[4]
NSU	865	0.46	364	0.42	43	0.297	0.243	0.205	0.294
NMOP	407	0.22	115	0.28	11	0.209	0.173	0.080	0.308
NMDLP	590	0.32	88	0.15	11	0.034	0.036	0.019	0.055
All	1,862	1.00	567	0.31	65	0.238	0.166	0.129	0.207

[1]ECSS = Ecological Classification System Section (NSU = Northern Superior Uplands; NMOP = Northern Minnesota & Ontario Peatlands; NMDLP = Northern Minnesota Drift & Lake Plains).
[2]Mean predicted probability of observing $\geq$1 pellet after adjusting for snow coverage (surrogate for detection), % jack pine and black spruce cover, a spatial gradient (X+Y), and the non-proportional allocation of sample points among ECSS.
[3]Lower 85% percentile confidence limit on mean predicted probability of observing $\geq$1 pellet.
[4]Upper 85% percentile confidence limit on mean predicted probability of observing $\geq$1 pellet.

Table 3. Sample statistics and count indices for a spruce grouse pellet survey at points (pts) in northern Minnesota during spring 2016.

ECSS[1]	No. possible sample pts	Prop. sample	No. survey pts	Sample fraction	No. routes	No. pts pellets detected	No. pts fresh pellets detected	No. pts roost piles detected	Mean pellet grp count[2]	SD[3]	Mean predict pellet-grp count[4]	85% LCL[5]	85% UCL[6]
NSU	865	0.46	364	0.42	43	108	27	98	5.2	6.20	0.64	0.41	1.04
NMOP	407	0.22	115	0.28	11	24	5	19	5.9	6.42	0.90	0.30	3.36
NMDLP	590	0.32	88	0.15	11	3	0	1	3.7	4.62	0.07	0.03	0.17
All	1862	1.00	567	0.3	65	135	32	118	5.3	6.18	0.70	0.32	1.12

[1]ECSS = Ecological Classification System Section (NSU = Northern Superior Uplands; NMOP = Northern Minnesota & Ontario Peatlands; NMDLP = Northern Minnesota Drift & Lake Plains).
[2]Mean pellet-group count (excluding zero counts).
[3]Standard deviation of the mean pellet-group count.
[4]Mean predicted pellet-group count after adjusting for snow coverage (surrogate for detection), % jack pine and black spruce cover, a spatial gradient (X+Y), and the non-proportional allocation of sample points among ECSS.
[5]Lower 85% percentile confidence limit on mean predicted pellet-group count after adjusting for snow coverage.
[6]Upper 85% percentile confidence limit on mean predicted pellet-group count after adjusting for snow coverage.

Table 4. The proportion of simulated 10-year periods of population decline (i.e., the state process; *n* = 200) for which the estimated trend in the index of use from simulated pellet-count surveys (i.e., the observation process) was negative, indicating sufficient sampling intensity. The simulations and estimated trends were based upon the real survey effort and pellet-count index data collected during 2016, including the observed spatial, temporal, and sampling variance.

ECSS[1]	Expected occupancy of survey points in year 1	Index of use in year 1	Mean growth rate in occupancy[2]	Growth rate of simulated populations			Proportion with negative estimated trend
				Min	Median	Max	
NSU	0.587	0.297	0.984	0.951	0.983	1.013	0.93
NMOP	0.676	0.209	0.972	0.936	0.987	1.031	0.79
NMDLP	0.110	0.034	0.935	0.811	0.937	1.081	0.91
All	0.531	0.238	NA	0.950	0.983	1.011	0.94

[1]ECSS = Ecological Classification System Section (NSU = Northern Superior Uplands; NMOP = Northern Minnesota & Ontario Peatlands; NMDLP = Northern Minnesota Drift & Lake Plains).
[2]The mean occupancy values used to simulate the populations corresponded to declines over 10 years of 15%, 25%, and 49% in the NSU, NMOP, and NMDLP sections, respectively.

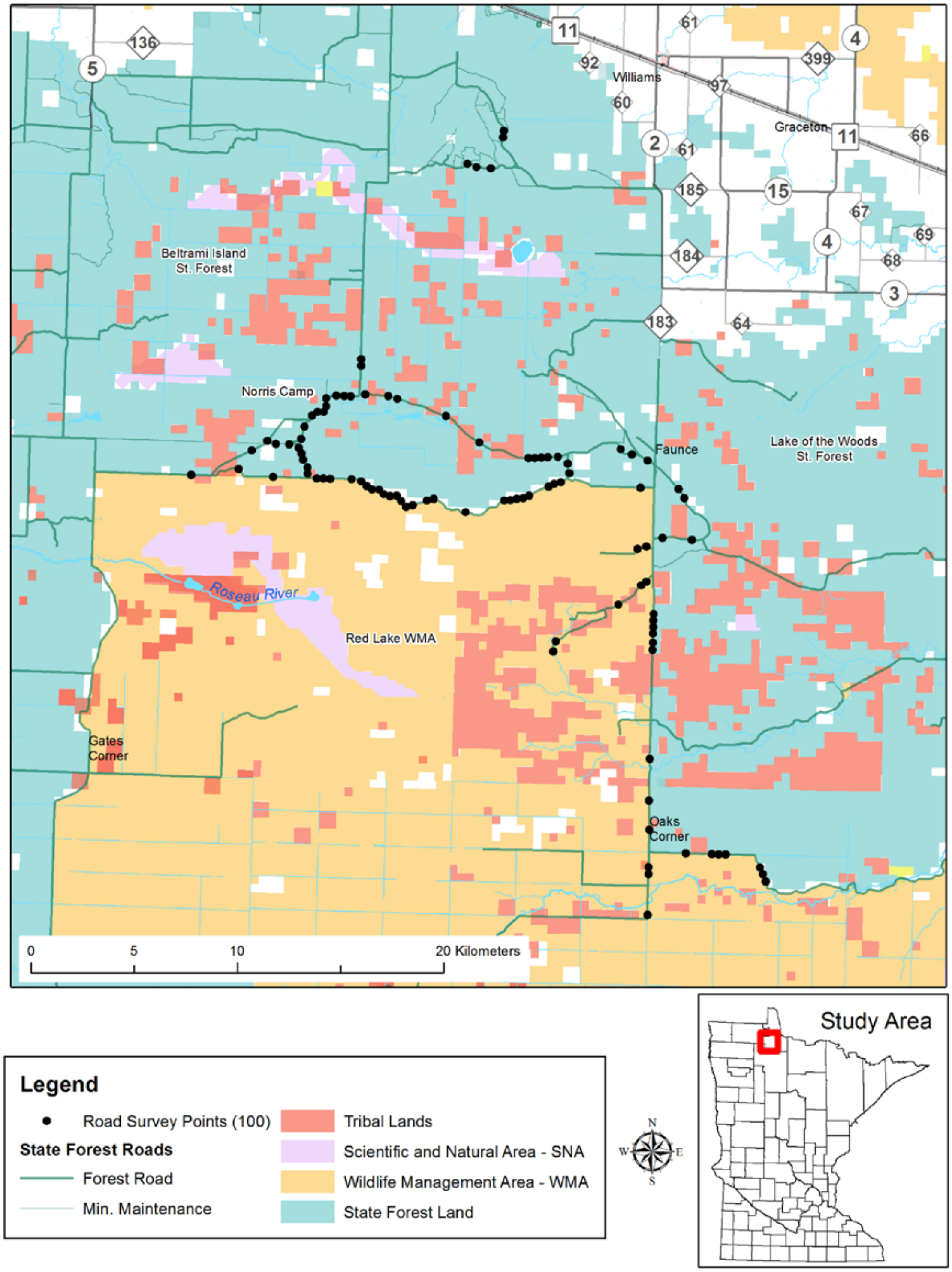


Figure 1. Study area at Red Lake Wildlife Management Area and Beltrami Island State Forest in Minnesota during 2015. The study area was reduced to focus on areas where spruce grouse were detected in 2014. Off-road points were 300 m from road points and alternated sides except when access was prohibited.

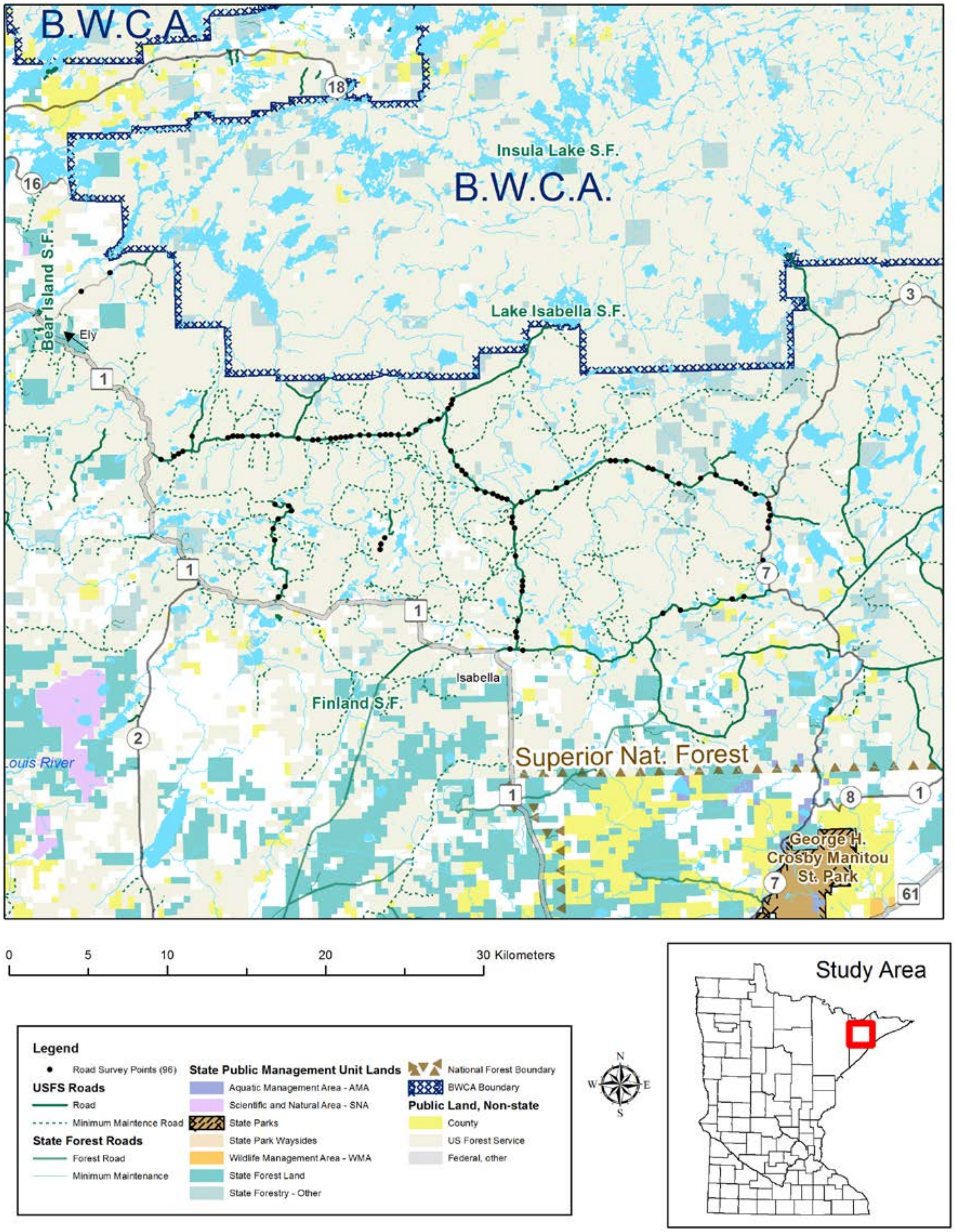


Figure 2. Study area near Isabella, Minnesota (NE) in 2015. Points indicate survey locations along roads. Off-road points were within 300 m of road points and alternated sides except when access was prohibited.

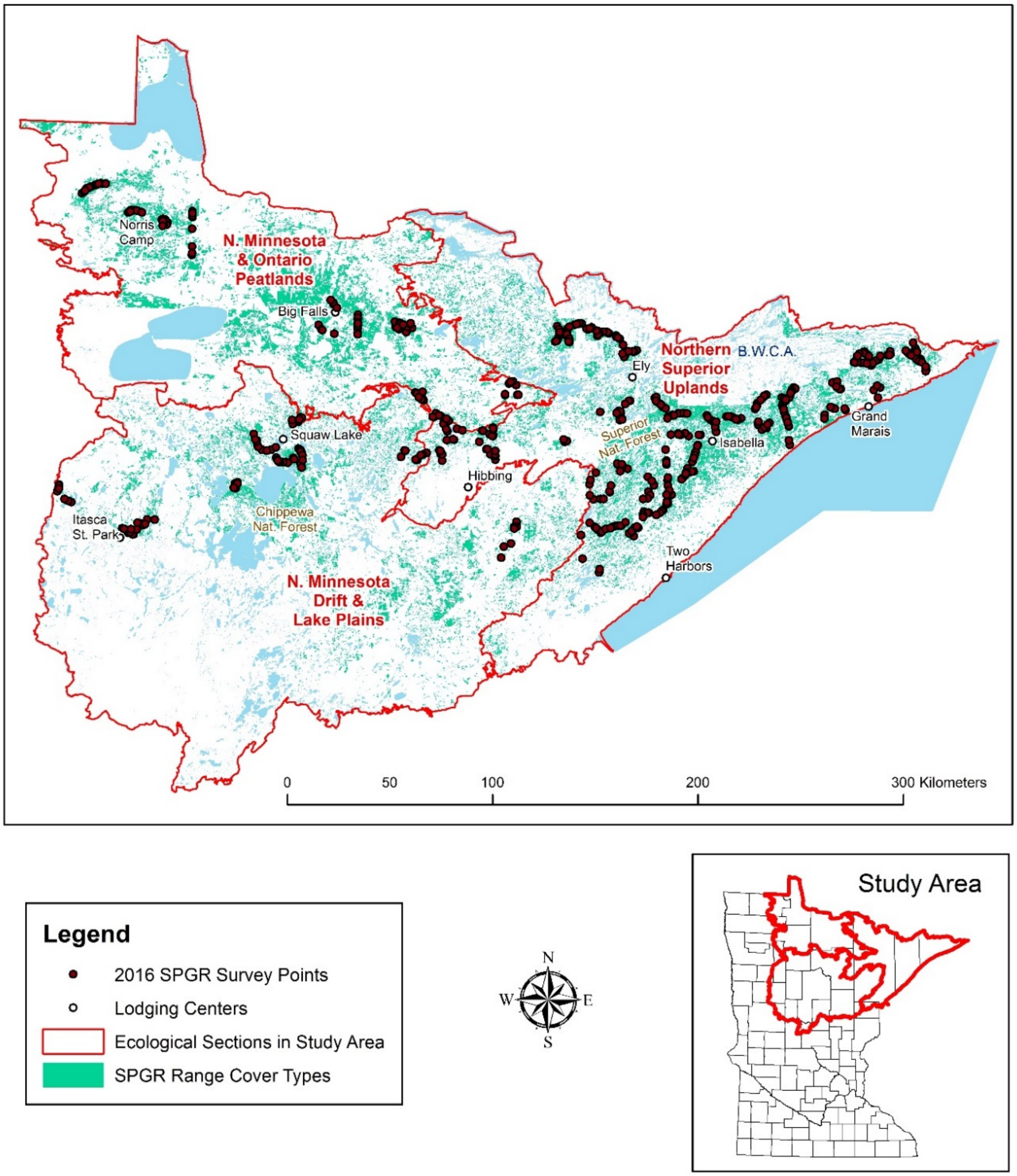


Figure 3. Spruce grouse study area in Minnesota during 2016. Survey points are depicted within the 3 Ecological Classification System sections.

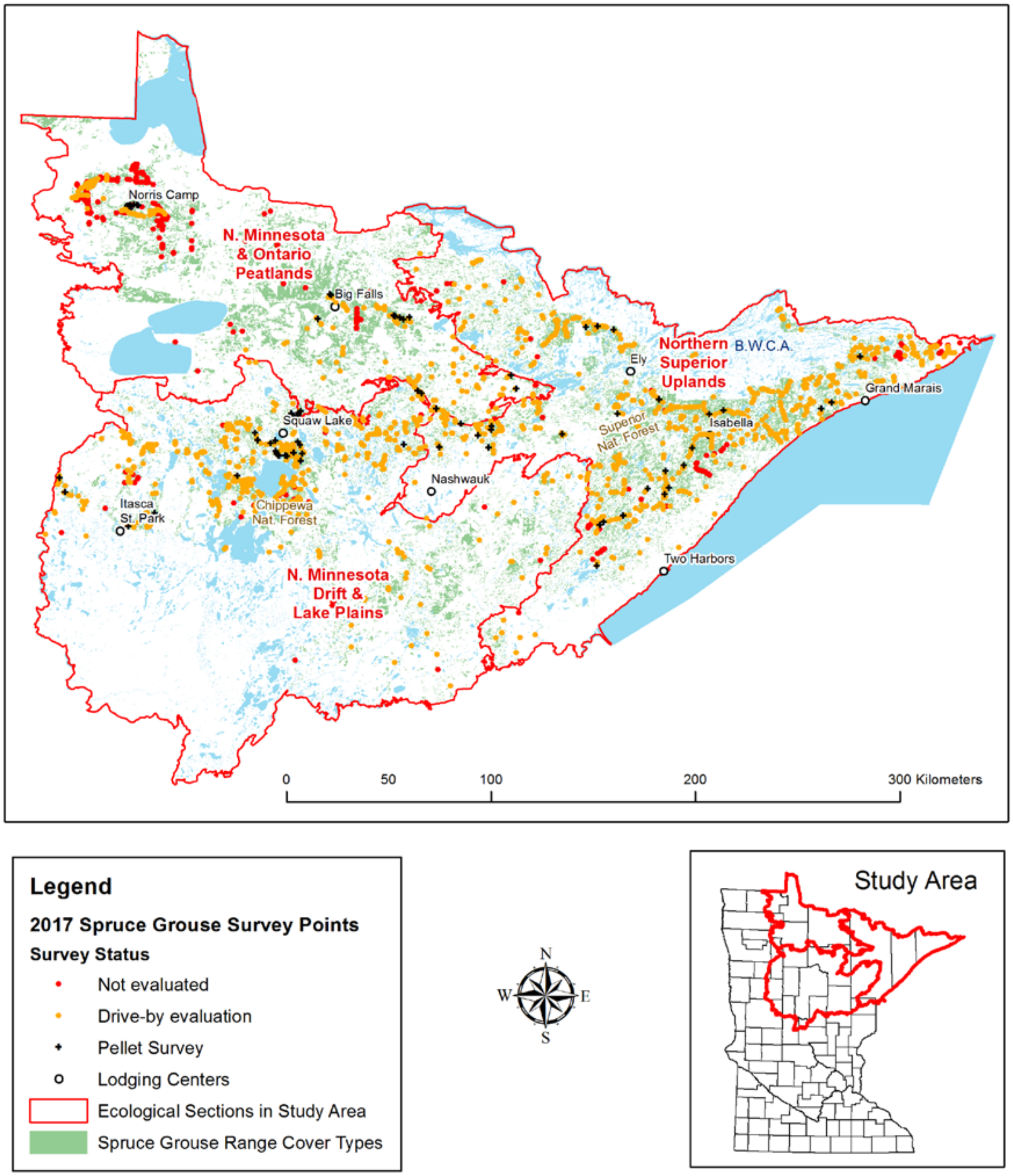


Figure 4. Spruce grouse study area in Minnesota during 2017. Survey points are depicted within the 3 Ecological Classification System sections.

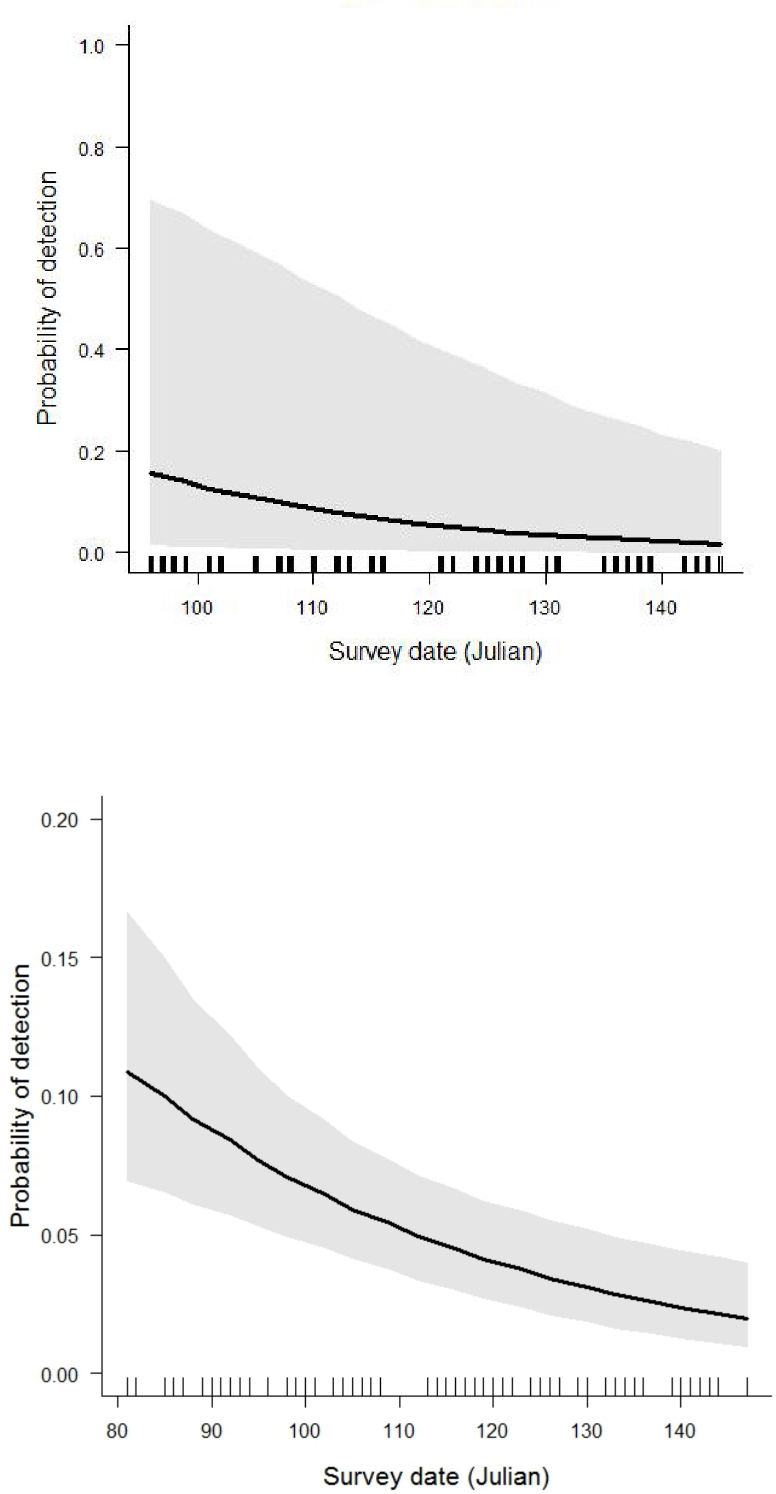


Figure 5. Mean conditional probability of detection (solid line; conditional on spruce grouse being present and available for detection) in each listening interval as a function of survey date at Red Lake Wildlife Management Area and Beltrami Island State Forest in 2014 (top) and both study areas in Minnesota during 2015 (bottom). Gray polygon denotes 95% confidence interval. The “rug” on the x-axis denotes the sample distribution.

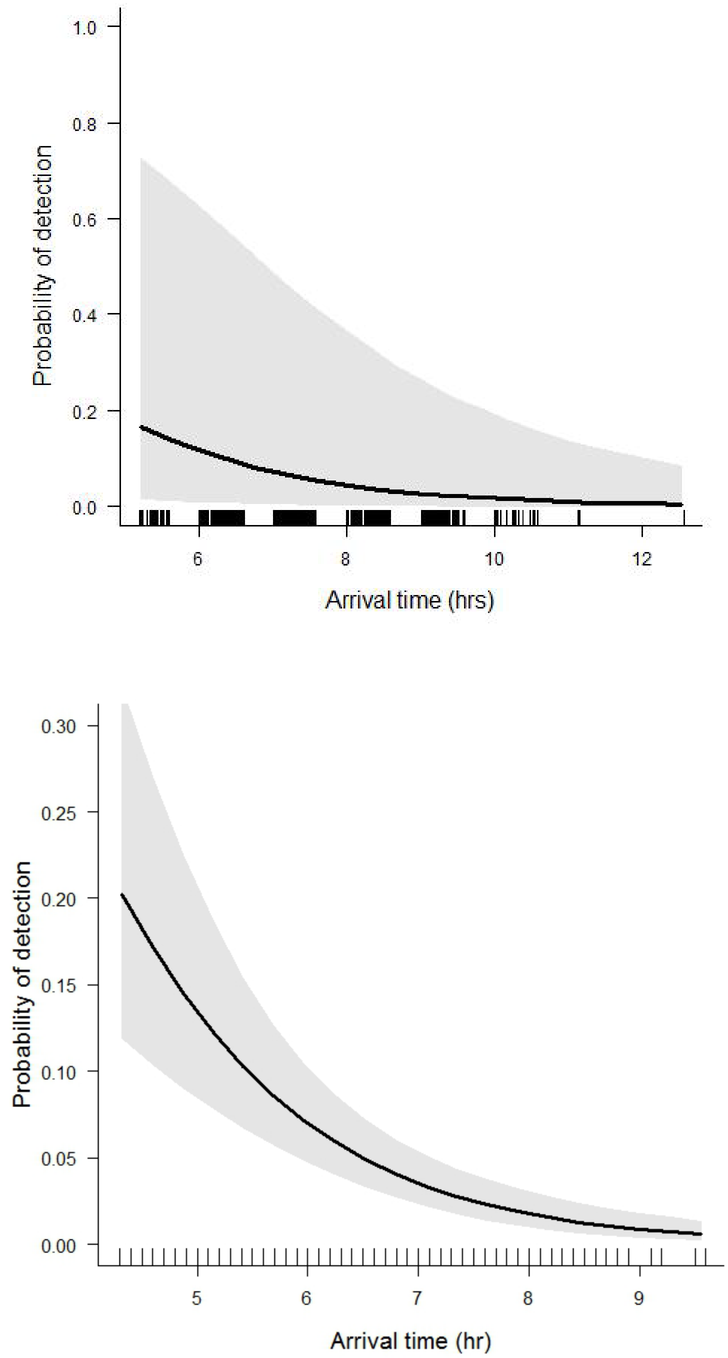


Figure 6. Relationship between spruce grouse call detections and cantus call survey arrival time (i.e., 6 = 0600 hours) at Red Lake Wildlife Management Area and Beltrami Island State Forest in 2014 (top) and in both study areas in Minnesota during 2015 (bottom). Gray polygon denotes 95% confidence interval.

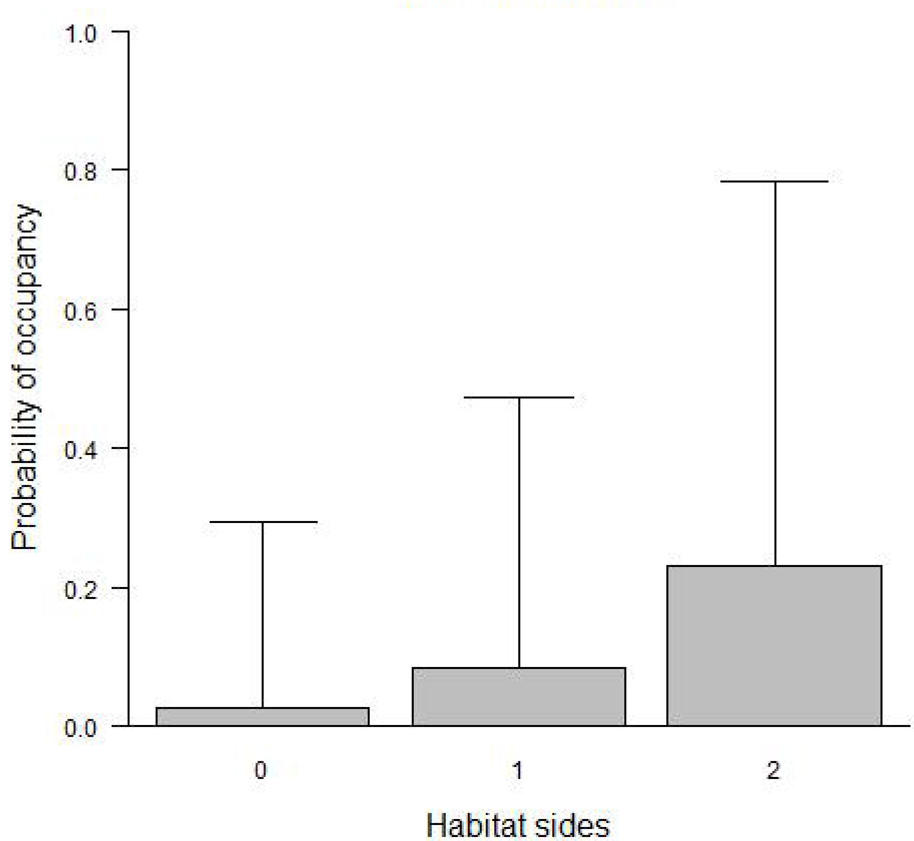


Figure 7. Relationship between the probability of spruce grouse occupancy and the presence of habitat on 0, 1, or 2 sides of the road during cantus call surveys at Red Lake Wildlife Management Area and Beltrami Island State Forest in Minnesota during 2014.

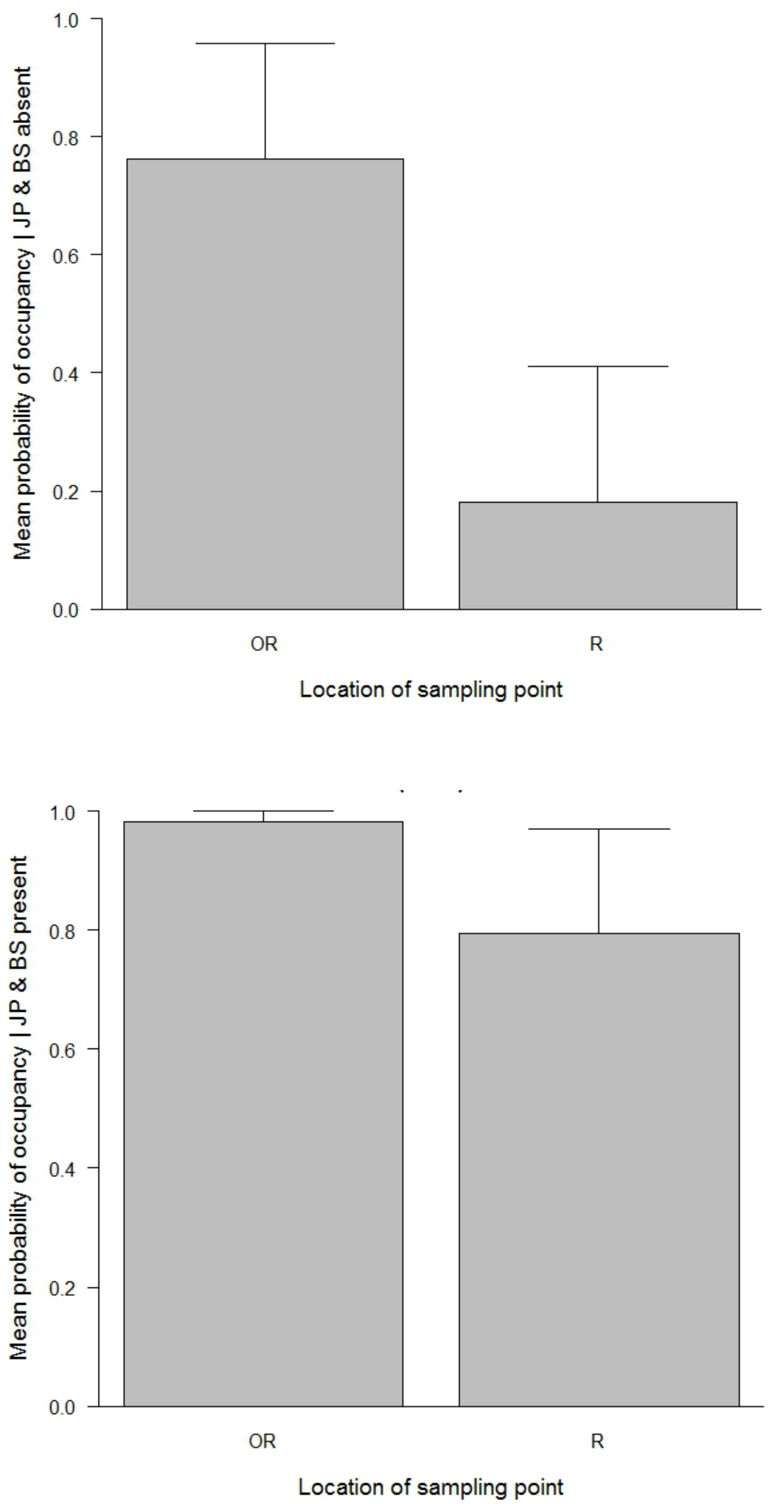


Figure 8. The mean probability of occupancy of spruce grouse at survey points located on roads (R) and off roads (OR) during cantus call surveys at points where jack pine or black spruce were not (top) and were (bottom) present in the Isabella, Minnesota (NE) study area in 2015.

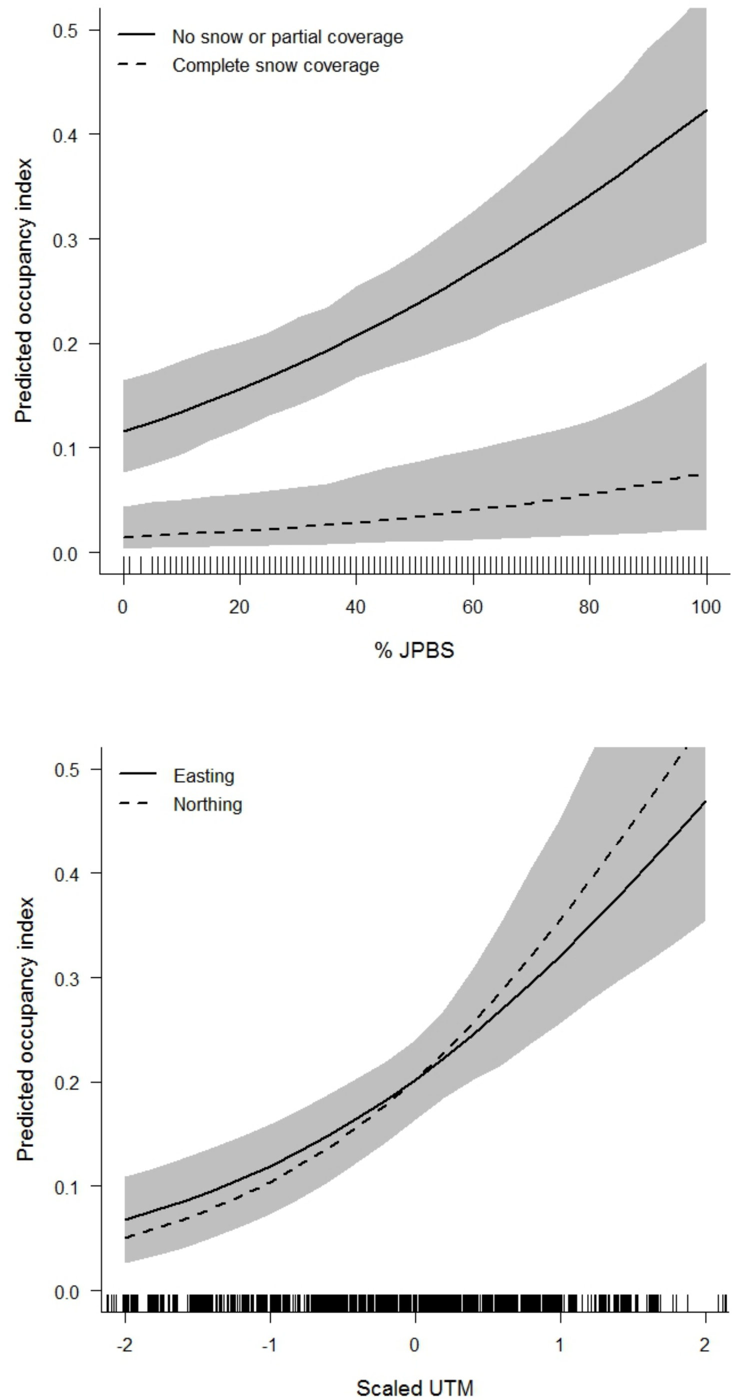


Figure 9. Mean probability of detecting spruce grouse pellets as a function of (A) percent cover of jack pine and black spruce habitats (%JPBS) and snow cover (surrogate for detection probability), and (B) the spatial location of survey points (with other covariates fixed at mean or base values). Figure is based on a generalized linear mixed-effects model fit to pellet-survey data in northern Minnesota during spring 2016.

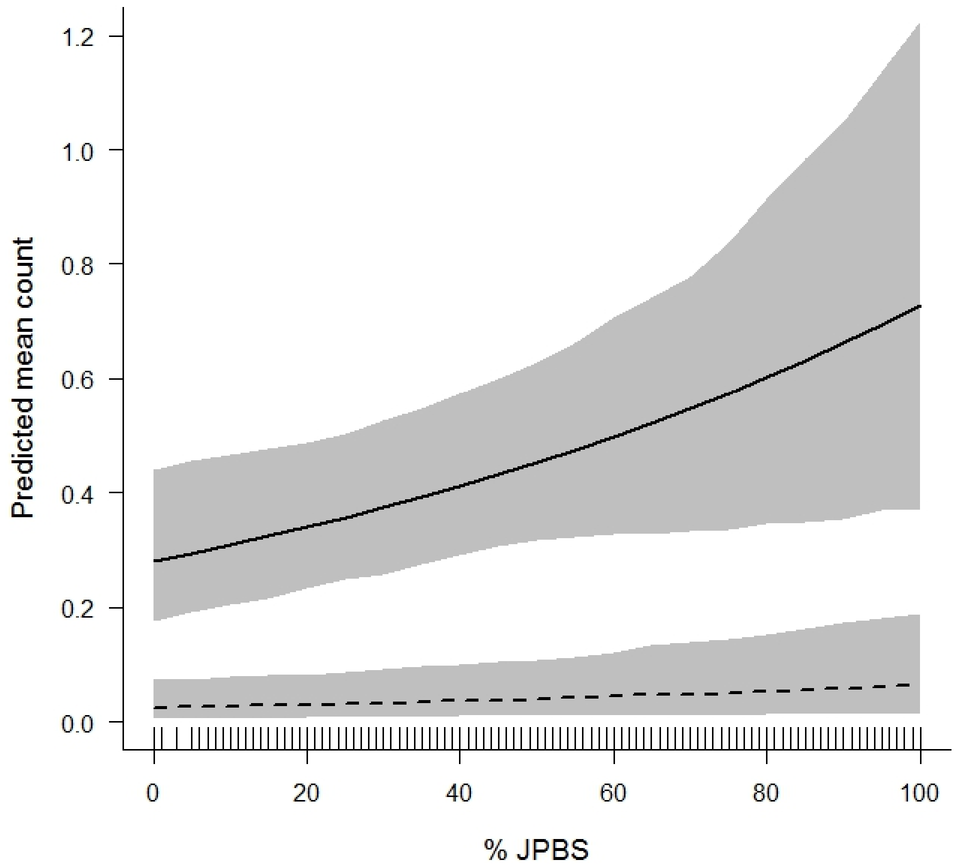


Figure 10. Mean count of spruce grouse pellet groups as a function of percent cover of jack pine and black spruce (%JPBS) habitats and snow cover (surrogate for detection probability). No snow or partial snow coverage is indicated by the solid line and the dashed line represents complete snow coverage. Figure is based on a generalized linear mixed-effects model fit to pellet-survey data in Minnesota during spring 2016.

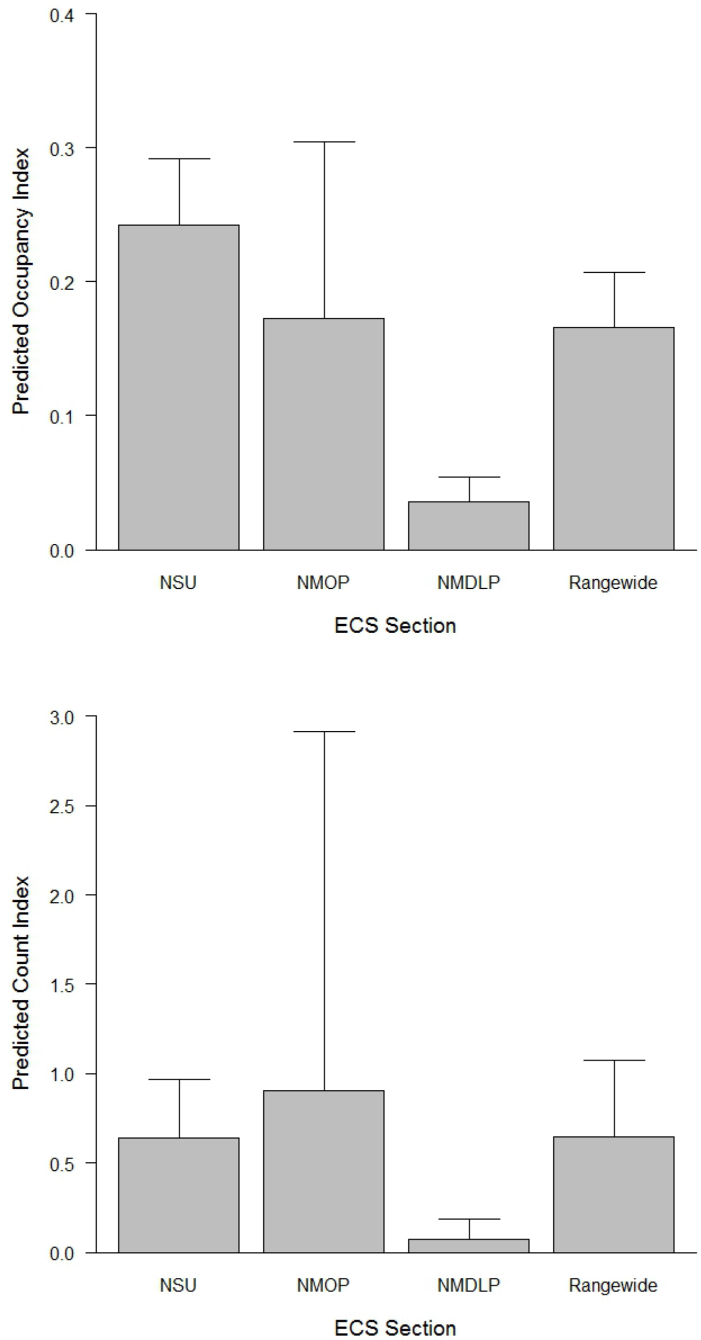
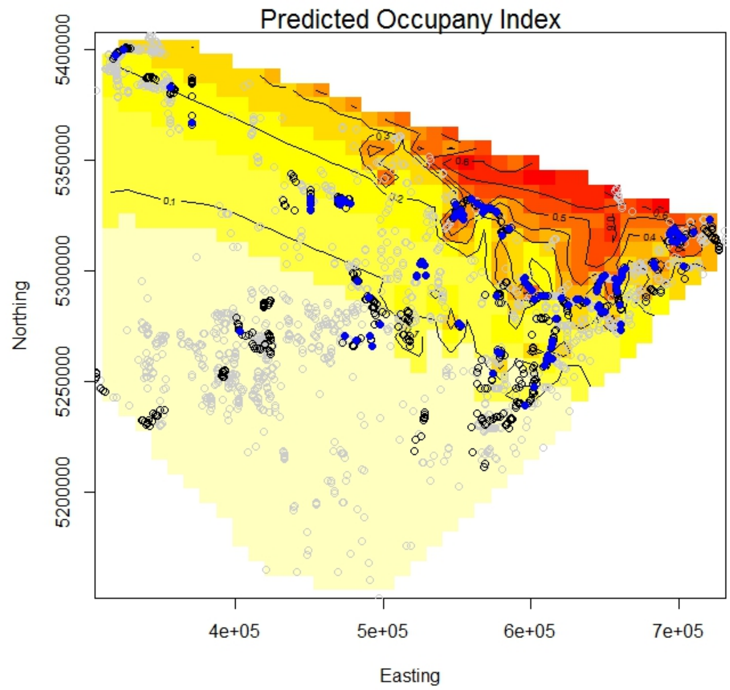


Figure 11. Potential monitoring metrics for spruce grouse in northern Minnesota during spring 2016. Figures are based on the arithmetic mean of model predictions applied to all potential roadside sampling points while holding the categorical predictor snow cover (surrogate for detection probability) to “None or partial.” Ecological Classification System (ECS) sections included Northern Superior Uplands (NSU), Northern Minnesota & Ontario Peatlands (NMOP), and Northern Minnesota Drift & Lake Plains (NMDLP).



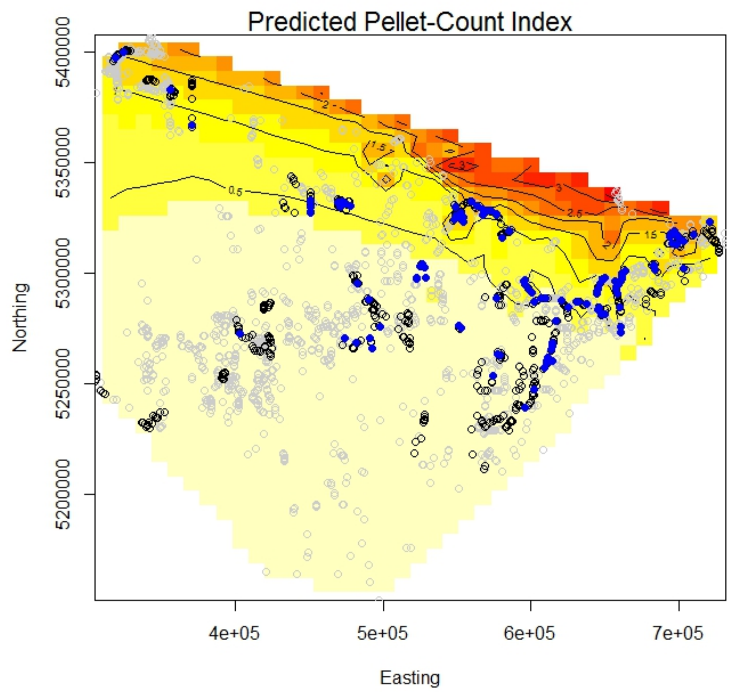


Figure 12. Smoothed prediction surface for spruce grouse monitoring metrics (red = highest; light yellow = lowest predicted index values) in northern Minnesota during spring 2016 based on a bivariate interpolation of model predictions. Contour lines with the highest predicted index values are also depicted.