Northern Goshawk Monitoring in the Bridger-Teton National Forests: 2009 Field Season Report

May, 2010

ROCKY MOUNTAIN BIRD OBSERVATORY

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    2. ***Education*** *is critical to the success of bird conservation.*
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Cover Photo*:* Picture by Jenny Berven. The Northern Goshawk is a non-releasable bird from Rocky Mountain Raptor Program, Fort Collins, CO

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EXECUTIVE SUMMARY

The Northern Goshawk is the largest accipiter found in North America and inhabits much of the forested land in the United States. As a species of concern in the state of Wyoming as well as a potential species to be listed under the Threatened and Endangered Species Act, the goshawk is in need for accurate assessments of population change and response to management practices. Since the bird's primary habitat is forested land, much of the bird's range falls within U.S. Forest Service's (USFS) administrative boundaries. These concerns and classifications lead to the publication of the "Northern Goshawk Inventory and Monitoring Technical Guide" by the USFS to aid regional mangers as well as local officials to develop and implement regional monitoring of goshawk populations. Through the use of presence/absence surveys, the guide outlines how occupancy modeling can be used to determine trends in a regional goshawk population.

In 2009, the Wyoming Game and Fish Department (WGFD) contracted Rocky Mountain Bird Observatory (RMBO) to assist in the development and implementation of goshawk monitoring using the technical guide as a reference. The area of study included the Bridger-Teton National Forests (BTNF) located in west-central Wyoming. The contract between these two entities was advantageous for WGFD because RMBO was working with the U.S. Forest Service's Rocky Mountain (RMR) and Southwest Region to conduct goshawk monitoring in forests throughout those regions during the same season. As the WGFD had funding to survey only a portion of the BTNF and wanted to obtain raptor data from the Wyoming and Salt River Mountain Ranges, this partnership allowed the surveys to take place on a smaller scale while maximizing cost and manpower.

The WGFD created a study design similar to the RMR and the Southwest Region's goshawk monitoring. The design mandated that broadcast acoustical surveys be conducted during two distinct time periods. Surveys were conducted in 10 randomly selected, 600-ha square Primary Sampling Units (PSUs) between 15 June – 5 September 2009, corresponding to the goshawk's nesting and fledging seasons.

Five of 10 PSUs and two of seven resurveyed PSUs had detections during the nestling and fledgling surveys, respectively. Data analysis concluded that the sample size was too small to return valid results using the BTNF data alone ("BT, simple") or using a covariate for effort ("BTρ(e)"). Therefore, RMR presence/absence data was used with BTNF data to increase sample size for BTNF monitoring.

Five different models were run, using differing sets or subsets of data, to determine occupancy for the BTNF:

1) "BT, RMRρ(f)", which used fixed RMR detection probabilities and applied them to BTNF data, estimated occupancy at 0.557 (CI: 0.237- 0.836).
2) "BT+RMRρ(t)", which used all of RMR's and BTNF's data and variable detection probabilities, estimated occupancy at 0.545 (CI: 0.233 - 0.826).
3) "BT+RMRρ(·)", which used all of RMR's and BTNF's data and a constant detection probability, estimated occupancy at 0.540 (CI: 0.232 - 0.821).
4) "BT+SHρ(t)", which used a subset of RMR's data (only PSUs surveyed in the Shoshone National Forest) and BTNF's data and variable detection probabilities, estimated occupancy at 0.550 (CI: 0.225 - 0.838).
5) "BT+SHρ(·)", which used Shoshone and BTNF data and a constant detection probability, estimated occupancy at 0.543 (CI: 0.226 - 0.829).

Models using the same set of data were directly compared to each other using Akaike's information criterion (AIC_c). Once the best model was selected, models using different sets of data were compared by evaluating standard error (SE), confidence interval (CI) and coefficient of variance (CV) values. The "BT+RMRρ(·)" model fit better when compared to "BT+RMRρ(t)" and had the lowest SE, CI and CV when compared to all other models.

The "BT+RMRρ(·)" occupancy estimates of 0.540 for the BTNF indicate there was a greater density of goshawks in the BTNF than in the RMR and Southwest Region in 2009 whose preliminary occupancy estimates are 0.475 (CI: 0.3614-0.5883) and 0.258 (CI: 0.133 - 0.383), respectively. However, because occupancy estimates are only used as a surrogate for abundance, occupancy should be primarily used to determine trends from year to year within a study area instead of across different study areas. Therefore, frequent goshawk monitoring using a constant study design is instrumental in determining trends in the population as well as evaluating positive or negative population responses to management decisions and practices.

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INTRODUCTION

The Northern Goshawk (*Accipiter gentilis*) is the largest of three accipiters found in North America (Squires and Reynolds 1997). The goshawk inhabits and nests in several classes of woodlands and forests including coniferous, deciduous and mixed forests ranging from Alaska to Mexico. Forest and woodland age class and structure preference varies throughout the bird's range and depends on the local forest types. For example, goshawks primarily occupy ponderosa pine, mixed coniferous and spruce-fir forests in the Southwest and pine forests interspersed with aspen groves in the forests of Colorado, Wyoming and South Dakota; whereas in the Great Basin, goshawks inhabit small patches of aspen within shrub-steppe habitat (Squires and Ruggiero 1996). However, a general consistency in the need for large, mature tree stands for nesting has been found as well as a correlation between prey base and population stability (Reynolds et al. 1992, Anderson et al. 2005).

Due to the difficulties associated with the low density of goshawks (≤12 nesting pairs/100-km2) mixed with the bird's cryptic behavior (Squires and Reynolds 1997), population estimates are undetermined across vast areas and therefore, the overall status of the goshawk's population remains unknown (Anderson et al. 2005, Woodbridge and Hargis 2006). For this reason and others, several agencies have listed the Northern Goshawk as a species of concern within their administrative boundaries (Woodbridge and Hargis 2006). Also, because the goshawk generally requires mature to old growth trees as nesting sites, the species can be used as an indicator of forest health (Reynolds et al. 1992, Anderson et al. 2005).

In 1996, the U.S. Fish and Wildlife Service (USFWS) was petitioned to list the goshawk as threatened or endangered. In 1998, the USFWS found that not enough was known about the species' population to warrant listing (United States Fish and Wildlife Service 1997;1998). These results catalyzed the development of a national bioregional monitoring program. In 2006, the U.S. Department of Agriculture, Forest Service (USFS) published the "Northern Goshawk Inventory and Monitoring Technical Guide" to assist their biologists in the development and implementation of monitoring programs to determine population trends within large administrative and bio- regions (Woodbridge and Hargis 2006).

The Rocky Mountain Region (RMR) of the USFS (which includes all National Forests in Colorado, the Big Horn, Medicine Bow and Shoshone National Forests in Wyoming and the Black Hills National Forest in South Dakota) and the Great Lakes Region have each completed at least one field season implementing bioregional monitoring. In 2009, the RMR and the Southwest Region (which includes all National Forests in Arizona and New Mexico) completed bioregional surveys.

Rocky Mountain Bird Observatory (RMBO) collaborated with the RMR to conduct the 2006 and 2009 bioregional surveys. This region stratified Primary Sampling Units (PSUs) by primary ("dominant conifer species and status of aspen") and marginal habitat (sub-alpine forests) and easy and difficult access (determined by distance from field offices and/or roads). In 2006, 51 PSUs were surveyed with an overall occupancy of 0.329 (CI: 0.213–0.445) and occupancy in primary and secondary habitat of 0.811 (SE = 0.113) and 0.124 (SE = 0.067), respectively. Preliminary results for the 109 PSUs surveyed in 2009, produce an overall occupancy of 0.475 (CI: 0.3614-0.5883) and occupancy in primary and secondary habitat of 0.838 (SE = 0.079) and 0.320 (SE= 0.070), respectively.

RMBO also collaborated with the Southwest Region to conduct the 2009 bioregional surveys in all National Forests in Arizona and New Mexico. The Southwest Region delineated 4 strata; stratum 1 = easy access ponderosa pine forests, stratum 2 = easy access piñon-juniper woodland/subalpine forests, stratum 3 = difficult access ponderosa pine forests and, stratum 4 =

difficult access piñon-juniper woodland/subalpine forests. Preliminary results for 105 PSUs surveyed in 2009, produced an overall occupancy of 0.258 (CI: 0.133 - 0.383) and occupancy in primary and secondary habitat of 0.418 (SE = 0.108) and 0.118 (SE = 0.054), respectively.

The Wyoming Game and Fish Department (WGFD) determined there was a need to emulate the bioregional survey methods in a more local scale within the Bridger-Teton National Forests (BTNF) located in the Greater Yellowstone ecosystem. Little research had been completed on goshawk populations within these forests. However, one report suggests that nest occupancy decreased from a baseline period of 1992-1995 to 1998-2002 in the Targhee National Forest located adjacent to the BTNF. This report showed a need for consistent monitoring efforts to determine goshawk occupancy trends in the area (Patla 2005). Furthermore, the WGFD lists the goshawk as a species of special concern because of the vulnerability of the bird's habitat and sensitivity to human disturbance (Wyoming Game and Fish Department 2004).

RMBO was contracted by WGFD to assist in the development and implementation of local monitoring for goshawks in the BTNF in congruence with a wider monitoring effort put forth by the RMR and Southwest Region. Occupancy modeling is the preferred method to assess status and changes in goshawk populations from year to year without the need for extensive abundance surveys (MacKenzie and Nichols 2004, Woodbridge and Hargis 2006). Occupancy modeling (hereafter referred to as occupancy) determines what fraction of a landscape is occupied by a species, whereas abundance determines how many individuals of a species are found within the landscape. Although occupancy modeling is not as accurate as abundance, it can be used as a surrogate for abundance because the two are positively correlated (MacKenzie and Nichols 2004).

METHODS

Study Area

The BTNF is located in western Wyoming south of Yellowstone National Park and within the Greater Yellowstone ecosystem. The BTNF encompasses 3.4 million acres, within which there are approximately 2.4 million acres of inventoried forested land. Engelmann spruce/subalpine fir comprise the largest portion of forest-types followed by lodgepole pine (44% & 16% respectively); (United States Forest Service. 2010b). The survey area concentrated around the Wyoming and Salt River Mountain Ranges within the National Forests and thus, resulted in most sites being located in the Bridger National Forest. Elevation within these mountain ranges generally exceeds 2,000m with several peaks above 3,000m.

Sampling Design and Method

The sampling design was based on the protocols established by the "Northern Goshawk Inventory and Monitoring Technical Guide" (Woodbridge and Hargis 2006). WGFD designed the sampling grid and randomly selected 15 PSUs to survey (Figure 1). PSUs were 600ha squares with 10 transect lines evenly spaced 200m apart and offset by 100m (Figure 2). On each transect line there were 12 call stations spaced 250m apart, for a total of 120 call stations per PSU. The limited budget did not allow us to select enough PSUs to stratify our sampling design. The 10 most accessible PSUs were selected by the field crew based on site accessibility and the capability of technicians to survey the location; limiting factors include: distance to roads, difficulty of terrain, and presence of impassible water and density of vegetation.

The "Northern Goshawk Inventory and Monitoring Technical Guide" (Woodbridge and Hargis 2006) was used to define survey protocols which were developed by Kennedy and Stahlecker

(1993). Technicians were responsible for conducting broadcast acoustical surveys during the nestling and fledgling stages of the goshawk breeding season.

Up to two visits were made to each PSU (one during the nestling season and one during the fledgling season). The nestling season usually occurs from June 1st through the end of June and the window for the fledgling season occurs from the end of June through August 15; however, to maximize detectability of goshawks in the region, input was received from district FS biologists and other scientists monitoring goshawk nests throughout the region to specify when eggs were expected to hatch. The nestling survey ended once the 10 PSUs were surveyed, which occurred before nestling began to fledge. The fledgling survey began once nestlings moved away from the nest (approximately when young are 34 days). Juvenile goshawks typically disperse from the area approximately 6 weeks after fledging. Once juveniles leave, broadcast acoustical surveys are no longer effective.

We surveyed all 10 PSUs during the nestling season. During the fledgling season, all PSUs without a nestling season detection and fifty percent of PSUs with a positive nestling season detection were resurveyed. We randomly selected PSUs with a positive nestling detection for fledgling season surveys.

Broadcast acoustical surveys were conducted at any time between 30 minutes before sunrise to 30 minutes before sunset, coinciding with goshawk activity (Woodbridge and Hargis 2006). Calling procedure followed protocols described in the monitoring technical guide (Woodbridge and Hargis 2006). Technicians broadcast one of three goshawk calls depending if it was during the nestling or fledgling surveys. During the nestling survey, an adult alarm call was broadcasted and during the fledgling survey, a juvenile food-begging call or a wail call was broadcasted. Technicians used FoxPro NX3 digital callers preloaded with the calls at a volume producing 80 to 110 dB output 1 meter from the speaker.

At each call station, technicians played one call for 10 seconds, then watched and listened for goshawk activity for 30 seconds then repeated the procedure after rotating 120 degrees. Once this procedure was done three times (and the circle completed), the technician would wait, watch and listen for two minutes then repeat the cycle. Technicians recorded any significant findings and time spent at each call station on a standardized field form. After two full rounds of playing the call, the technician would then move on to the next call station, while searching the surrounding area for any goshawks.

Technicians surveyed all call stations located in suitable habitat that could be safely reached until all surveyable stations were visited or until a goshawk detection was made. A call station in safe, suitable habitat was located within 150 of tree cover, on a slope less than 36 degrees and not located in water. A positive detection consisted of a visual or aural observation, finding an active nest and/or finding a freshly molted feather. If a bird was seen, sex and age was recorded, if known. Compass bearing of bird's approach and departure, station number and distance from transect was also recorded. Aural detections should have been followed by an attempt to get a visual of the bird to determine age and sex.

Field Personnel

Biological field technicians who had previous field experience working with goshawks, including knowledge of goshawk behavior, vocalizations and sign were highly desired for each team of two. However, most applicants did not have such experience and therefore, individuals were paired according to their overall field experience. Technicians with more experience (usually at least two years of avian fieldwork) were paired with an individual with less avian field research. Furthermore, unpaid interns were hired to assist field crews with surveying. For all individuals, experience hiking in remote areas and a good work ethic were required.

All technicians received training in goshawk identification. Training emphasized identification by visual and aural cues, feather and other indicators of goshawk presence. We also trained technicians in survey and data collection protocol. The training was conducted by USFS personnel in the first week of June near Steamboat Springs, CO. This was while goshawks were occupying known territories but before eggs had hatched. This allowed technicians to see suitable goshawk habitat.

Data Analysis

A presence/absence model was fit in program MARK (White and Burnham 1999) to determine detection probabilities (ρ) and occupancy (ψ) for each survey period using only the BTNF data. The sampling variances and standard errors of the combined estimates were approximated using the delta method (Powell 2007) in program SAS (PROC IML, SAS Institute 2008).

An additional model accounting for variation in survey effort was created because some PSUs contained call points in suitable habitat that were inaccessible. The model included a covariate where the probability of detection was modeled as a function of the percentage of call points completed in suitable habitat. A call station was considered to be in suitable habitat if it was within 150 meters of tree cover and on a slope no steeper than 36°. The survey effort covariate was calculated for each PSU by dividing the number of completed call points by the total number call points in suitable habitat and multiplying by 100.

Further analyses used supplemental data from the 2009 RMR's monitoring effort to determine detection probabilities and occupancy using program MARK. Two methods were used:

1. Detection probabilities determined by the RMR data were used as fixed parameters to find occupancy in the BTNF, and
2. RMR data were combined with BTNF data to determine detection probabilities and occupancy (Appendix A).

Using the second approach, we compared two models using Akaike's information criterion (AIC_c), (Burnham and Anderson 2002). The first model used different detection probabilities (between the fledgling and nestling periods) to determine occupancy and the second model used a constant detection probability to determine occupancy. Furthermore, the RMR data could be used in two possible ways. The first was to use all of the RMR data along with the BTNF data and the second was to use a subset of the RMR data that represent habitats most similar to those found in the BTNF.

As stated before, the sampling variances and standard errors of the combined estimates were approximated using the delta method (Powell 2007) in program SAS (PROC IML, SAS Institute 2008). α-levels = 0.05; Confidence intervals are at 95%.

RESULTS

Based on the input from local scientists, hatching occurred on or close to 15 June 2009. Goshawks in monitored nests began leaving the immediate nest area on or around 25 July 2009. This allowed the fledgling survey to continue through 5 September 2009. The nestling surveys in the BTNF occurred between 6 July and 21 July 2009. The fledgling surveys occurred between 10 August and 2 September 2009.

Five of the 10 PSUs surveyed during the nestling period had positive detections (Table 1, Figure 3). Seven PSUs were resurveyed during the fledgling period (Table 1). Two of the seven resurveyed PSUs had positive detections during the fledgling surveys (Table 1, Figure 4). The positive detections occurred in the same PSUs that had positive detections during the nestling surveys. All detections had visual confirmations and all goshawks sighted were adult birds. No active nests were found during surveying.

Table 1. Survey results for each Primary Sampling Unit (PSU) for Northern Goshawk monitoring.

PSU ID	Nestling Survey	Fledgling Survey
1	No detection	No detection
2	Detection	N/A†
3	Detection	Detection
4	No detection	No detection
5	Detection	Detection
6	Detection	N/A
7	No detection	No detection
8	Detection	N/A
11	No detection	No detection
15	No detection	No detection

† N/A=PSU was not surveyed a second time.

Overall naïve occupancy was 0.412 (SE = 0.123). Naïve occupancy was 0.50 (SE=0.167) for nestling surveys and 0.286 (SE = 0.184) for fledgling surveys. Effort was determined in the field by technicians for each PSU by counting each call station within the PSU that was accessible and located in suitable habitat (Table 2).

Table 2. Survey effort per Primary Sampling Unit (PSU) for Northern Goshawk monitoring.

PSU ID	# of Surveyed Call Stations †	Survey Effort ¤ %
1	7	6
2	61	51
3	80	67
4	35	29
5	66	55
6	47	39
7	73	61
8	119	99
11	74	62
15	76	63

† Call station is in a location that is accessible and has suitable habitat (slope < 36° and tree cover <150m away).
¤ Effort calculated by dividing the number of accessible and suitable call stations by 120 (total possible number of call stations) and multiplying by 100.

A model convergence occurred when running the data through program MARK for both the simple model (BT, simple) and the model accounting for variation in survey effort (BTρ(e)). The occupancy estimates were equal to one with very low standard errors. These results imply that the sample size is too small for the program to properly analyze.

The highest occupancy estimation for the BTNF PSUs was calculated using the fixed RMR's 2009 nestling and fledgling survey detection probabilities (BT, RMRρ(F)) 0.722 & 0.632, respectively, with the result of 0.557 (CI: 0.237- 0.836; Table 3).

The model combining RMR data and BTNF data, using variable detection probabilities (BT+RMRρ(t)), resulted in an occupancy estimation of 0.545 (CI: 0.233 - 0.826) with nestling and fledgling survey detection probabilities of 0.754 & 0.663, respectively (AIC_c = 234.6; Table 3, Figures 5 & 6). The second model combining RMR data and BT data, using a constant detection probability (BT+RMRρ(·)), resulted in the lowest occupancy estimation of 0.540 (CI: 0.232 - 0.821), with a detection probability of 0.727 (AIC_c = 233.2; Table 3, Figures 5 & 6).

The model combining the Shoshone and BTNF data, using variable detection probabilities (BT+SHρ(t)), resulted in an occupancy estimate of 0.550 (CI: 0.225 - 0.838) with nestling and fledgling survey detection probabilities of 0.773 & 0.598, respectively (AIC_c = 65.3; Table 3, Figures 5 & 6). The final model, combining Shoshone and BTNF data, using a constant detection probability (BT+SHρ(·)), resulted in an occupancy estimation of 0.543 (CI: 0.226 - 0.829) with a detection probability of 0.718 (AIC_c = 61.6; Table 3, Figures 5 & 6).

Table 3. Modeling results for Northern Goshawk monitoring.

Data Set	Parameter	Estimate	Standard Error	Coefficient of Variance	Confidence Interval
BT, simple	$\rho_{nestling}$	Null	-	-	-
	$\rho_{fledgling}$	Null	-	-	-
	ψ	Null	-	-	-
BTρ(e)	$\rho_{nestling}$	Null	-	-	-
	$\rho_{fledgling}$	Null	-	-	-
	ψ	Null	-	-	-
BT, RMRρ(f)	$\rho_{nestling}$	0.722	nc[§]	nc	nc
	$\rho_{fledgling}$	0.632	nc	nc	nc
	ψ	0.557	0.176	nc	0.237 - 0.836
BT+RMRρ(t)	$\rho_{nestling}$	0.754	0.070	0.093	0.594 - 0.865
	$\rho_{fledgling}$	0.663	0.096	0.145	0.458 - 0.821
	ψ	0.545	0.174	0.319	0.233 - 0.826
BT+RMRρ(·)	$\rho_{constant}$	0.727	0.065	0.090	0.583 - 0.835
	ψ	0.540	0.172	0.319	0.232 - 0.821
BT+SHρ(t)	$\rho_{nestling}$	0.773	0.144	0.186	0.405 - 0.944
	$\rho_{fledgling}$	0.598	0.209	0.349	0.214 - 0.891
	ψ	0.550	0.182	0.330	0.225 - 0.838
BT+SHρ(·)	$\rho_{constant}$	0.718	0.135	0.188	0.408 - 0.904
	ψ	0.543	0.178	0.327	0.226 -0.829

§ - Value not calculated.

DISCUSSION AND RECOMMENDATIONS

The need to develop and implement local, smaller-scale Northern Goshawk monitoring is essential to provide reliable data for the evaluation of the goshawk's status. Not only have the wildlife officials within the state of Wyoming determined that the goshawk is a species of special interest within the state, the national "Northern Goshawk Inventory and Monitoring Technical Guide" (Woodbridge and Hargis 2006) also calls for the development and implementation of forest-level and large-scale bioregional monitoring to obtain consistent, reliable information on local response of goshawk populations to management actions.

Using the naïve occupancy estimates is not as appropriate as using occupancy estimates that incorporate detection probabilities because naïve occupancy assumes the detection probability is equal to one. However, due to the goshawk's cryptic nature, size of territory, low densities, human error and prior bioregional monitoring results, we know that the detection probability is less than 100 percent and therefore, the naïve occupancy underestimates true occupancy (MacKenzie and Nichols 2004, Woodbridge and Hargis 2006).

The data collected during this survey needed to be combined with other sources of information because the sample size was too low to determine detection probability for the 10 PSUs surveyed in the BTNF and the naïve occupancy estimate is questionable. One option for data analysis was using the detection probabilities calculated for the RMR's 2009 surveys. Although habitat varied between the BTNF and several of the forests in the RMR (which include a significant proportion of ponderosa pine forests), the RMR does include the Shoshone National Forest, which, like the BTNF, is part of the Greater Yellowstone ecosystem. Therefore, the RMR's detection probabilities are averaged across a large bioregion that includes several forest types, including similar types found in the BTNF (United States Forest Service. 2010b). Furthermore, the data collected for the RMR was collected at the same time as the BTNF surveys. The Southwest Region also conducted surveys during the same time; however, the forests in the Southwest Region are almost entirely ponderosa pine forests and piñon-juniper woodlands and are significantly different than the BTNF (United States Forest Service. 2009).

Another option was to combine the data collected in the BTNF with other RMR data and disregard variations in stratification to determine an overall occupancy rate. This method is more accurate than just applying detection probability to the model because it includes the BTNF PSUs as well as PSUs in surrounding areas to determine occupancy by increasing the sample size to a value significant enough to get valid results from program MARK. The differences in stratification between habitat types are not a concern because the RMR's data can be separated by nestling and fledgling visits, which is the same as the BTNF methodology. However, this method also incorporates forest-types slightly different from the BTNF, such as the Black Hills National Forest which is mainly composed of ponderosa pine (United States Forest Service. 2010a).

The final option for data analysis was using the Shoshone PSU data from the RMR monitoring efforts in combination with BTNF PSU data. 12 Shoshone PSUs were visited at least one time during the same time periods (Appendix A). This method is the most biologically relevant way to analyze the BTNF data with supplemental data to increase sample size to a viable number because the Shoshone National Forest is also part of the Greater Yellowstone ecosystem and are comprised of similar forest types (United States Forest Service. 2010c).

The models within each data set were evaluated for better fit by comparing AIC_c values. For both the data set that combines all of the RMR data with the BTNF data and the data set that combines the Shoshone data with the BTNF data, the BT+RMRρ(·) & BT+SHρ(·) models were a better fit than the variable detection probability models. There is no appropriate way to directly compare the different models using different data sets with the AIC_c value so a general interpretation of the standard error, confidence interval and coefficient of variance were used. Although occupancy estimates only vary slightly (Table 3, Figure 5), the BT+RMRρ(·) model should be used to determine occupancy for the BTNF.

For future monitoring efforts, it is still undetermined how to continue surveying for occupancy within the BTNF and obtain valid results. One option is to increase sample size within the forests. However, there is no recommended cut-off sample size to obtain valid results because so many factors contribute to the model; including, but not limited to, the number of sites, detection probability and number of surveys conducted within the survey timeframe (MacKenzie and Royle 2005). If an acceptable standard error is established and several variables are assumed, a sample size can be determined using the equation:

$$\mathrm{var}(\hat{\psi}) = \frac{\psi}{s}\left[(1-\psi) + \frac{p^*(1-p^*)}{(p^*)^2 - K^2p^2(1-p)^{K-1}}\right]$$

where var$(\hat{\psi})$ = asymptotic variance, ψ = occupancy; *s* = sample size; $p^*= 1-(1-p)^K$; *p* = detection probability; and K = number of surveys at each site. Furthermore, the suggested number of surveys (K) is dependent on occupancy and detection probability in removal sampling designs, such as the goshawk monitoring surveys.

Another option would be to increase the number of times each PSU is surveyed (K) within the breeding season. MacKenzie and Royal (2005) suggest that it is actually more precise to perform occupancy studies in this way. However, if this method is used in the future, complications will arise if results from the 2009 surveys are compared to future surveys or if occupancy rates between the BTNF surveys are compared to other goshawk monitoring surveys that only visit PSUs twice a year. Furthermore, defining a sample size with K as the primary factor still involves the same complications associated with increasing sample size.

Whichever methods are used for future surveys, the data need to be collected and analyzed the same way as they have been in this report to be able to directly compare any additional surveys. This includes resurveying the same ten PSUs year to year. Maintaining sampling consistency allows trends in goshawk occupancy to be determined from year to year. The “Northern Goshawk Inventory and Monitoring Technical Guide” (Woodbridge and Hargis 2006) states that if a 20 percent of greater change occurs in a five-year period, the bioregional coordinator should assemble wildlife and forestry professionals to evaluate if an immediate change in land management is required. Finally, consistent sampling can be used to determine how changes in occupancy are related to changes in habitat and other management practices. With this knowledge, recommendations can be made to officials to modify management practice to help maintain or increase goshawk populations within the area of study.

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Figure 1. Northern Goshawk Monitoring in the Bridger-Teton National Forests, Randomly Selected Primary Sampling Units.

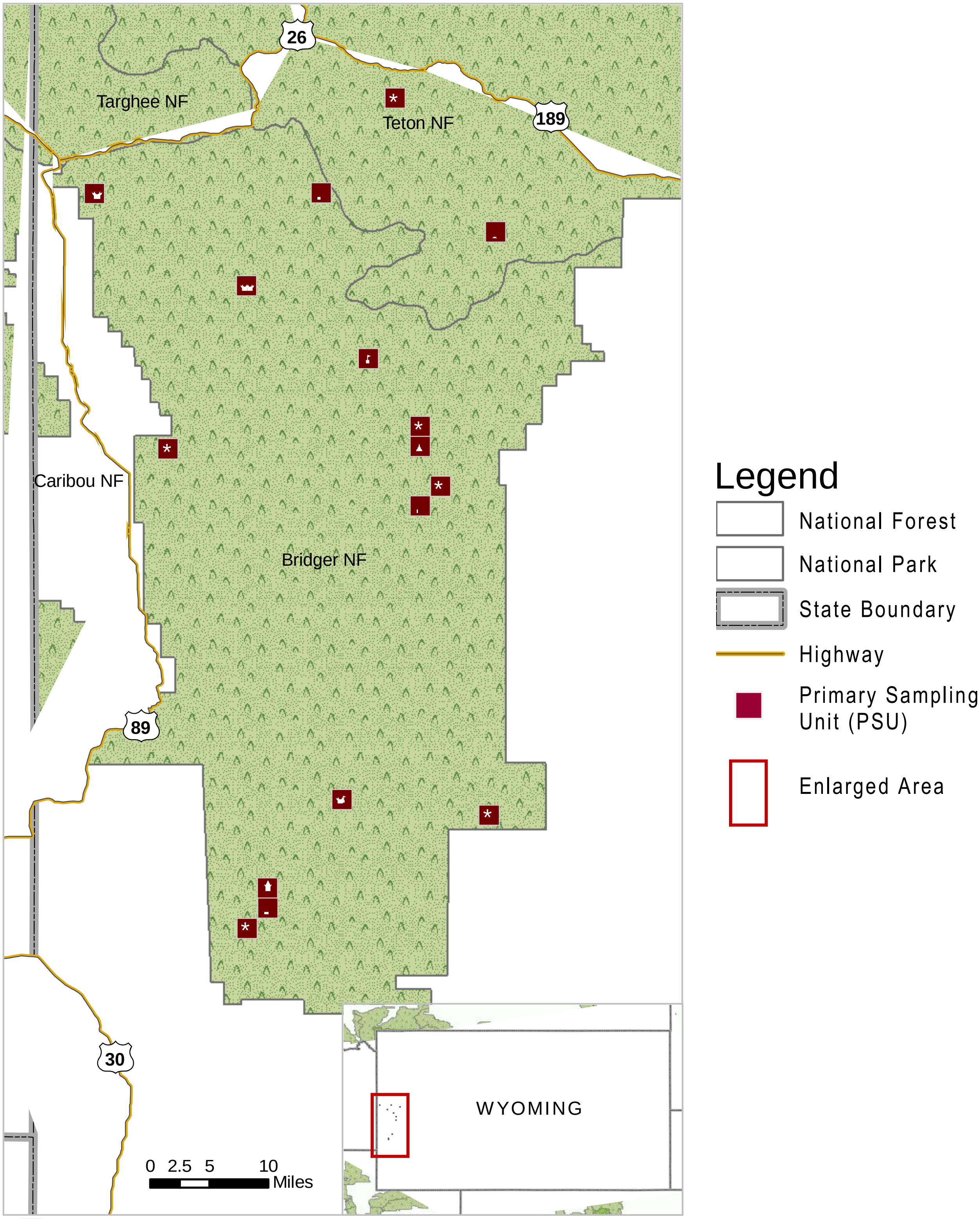


Figure 2. Northern Goshawk Monitoring, Primary Sampling Unit Example.

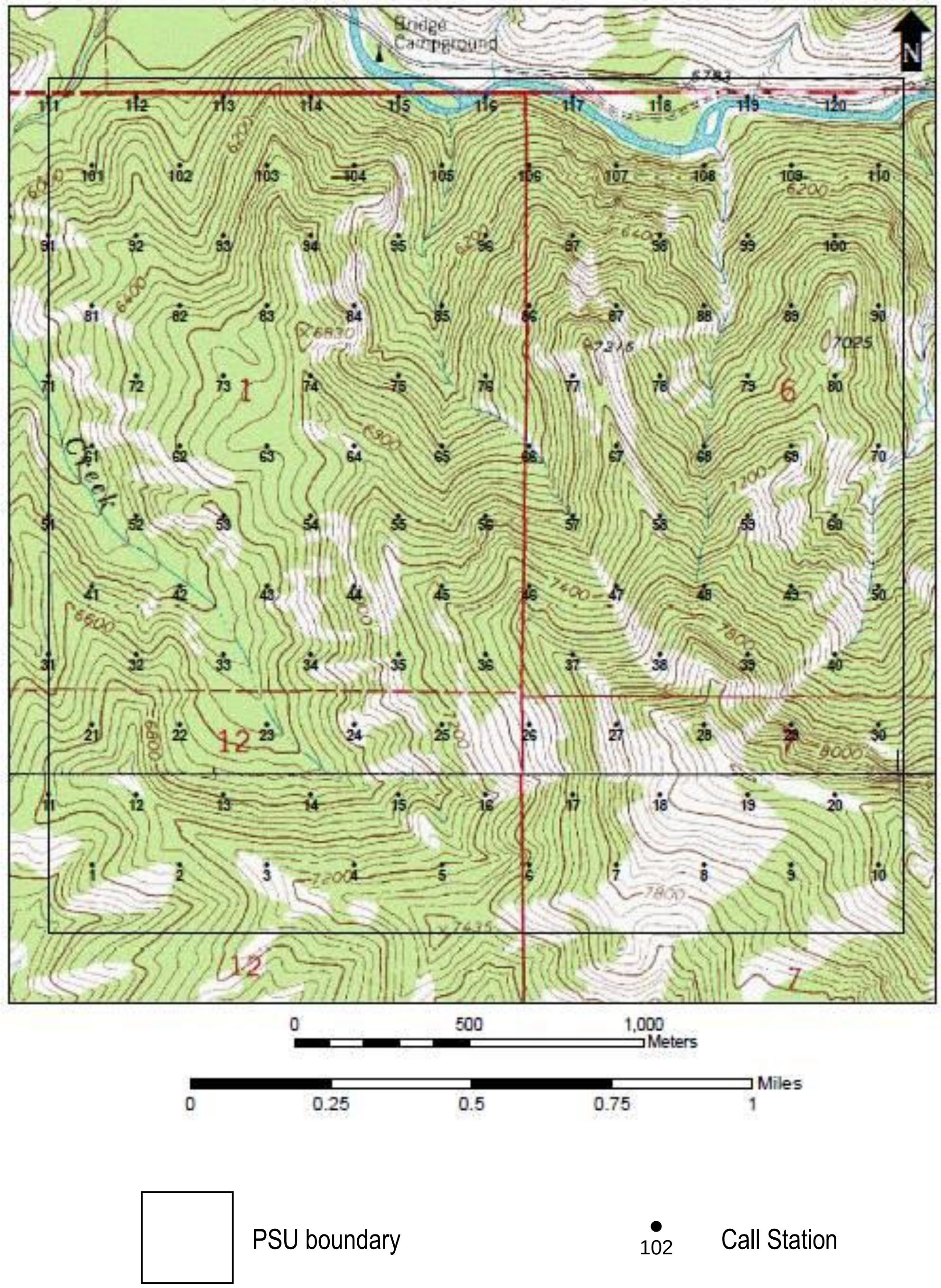


Figure 3. Northern Goshawk Monitoring in the Bridger-Teton National Forests, Results for Nestling Surveys.

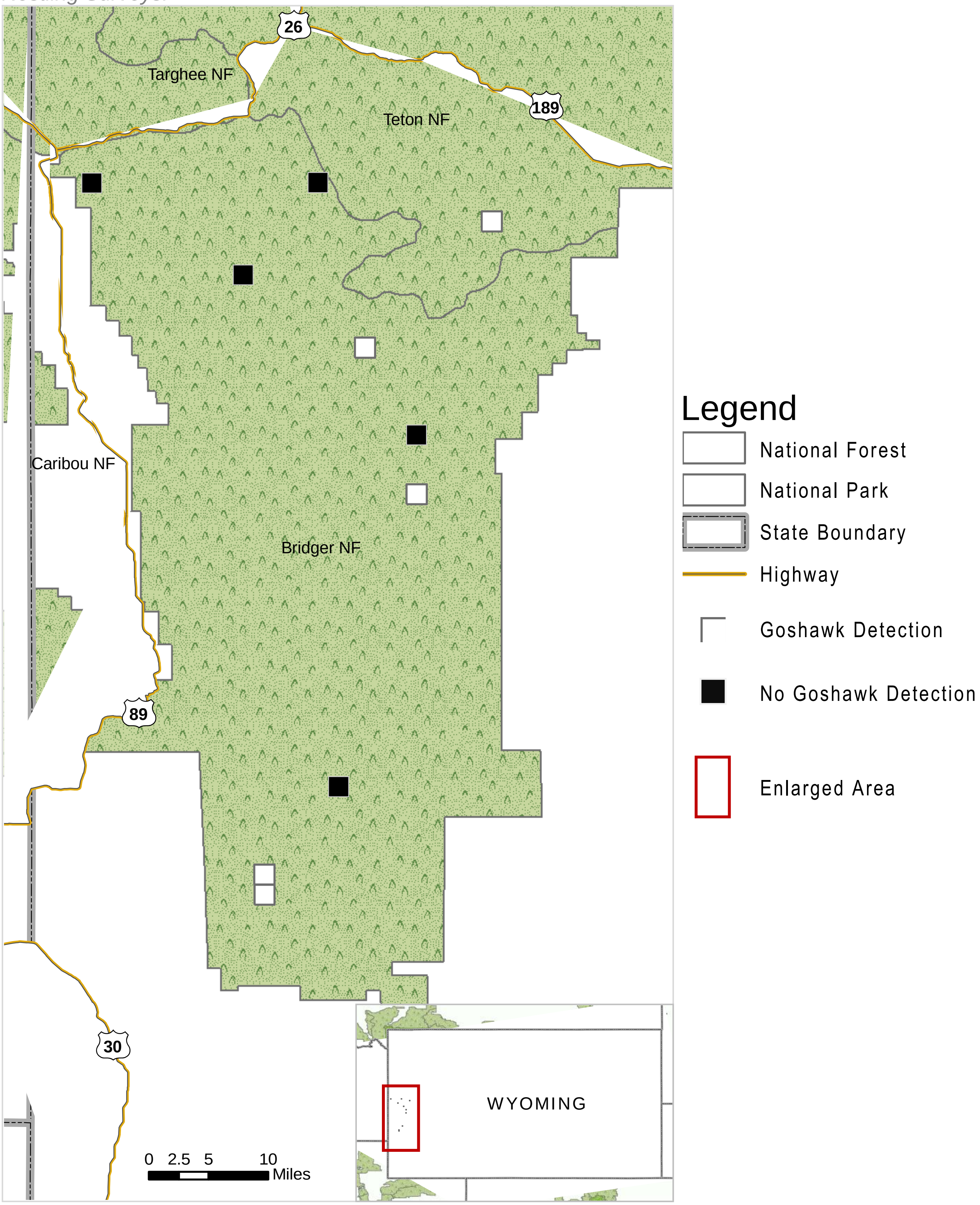


Figure 4. Northern Goshawk Monitoring in the Bridger-Teton National Forests, Results for Fledgling Surveys.

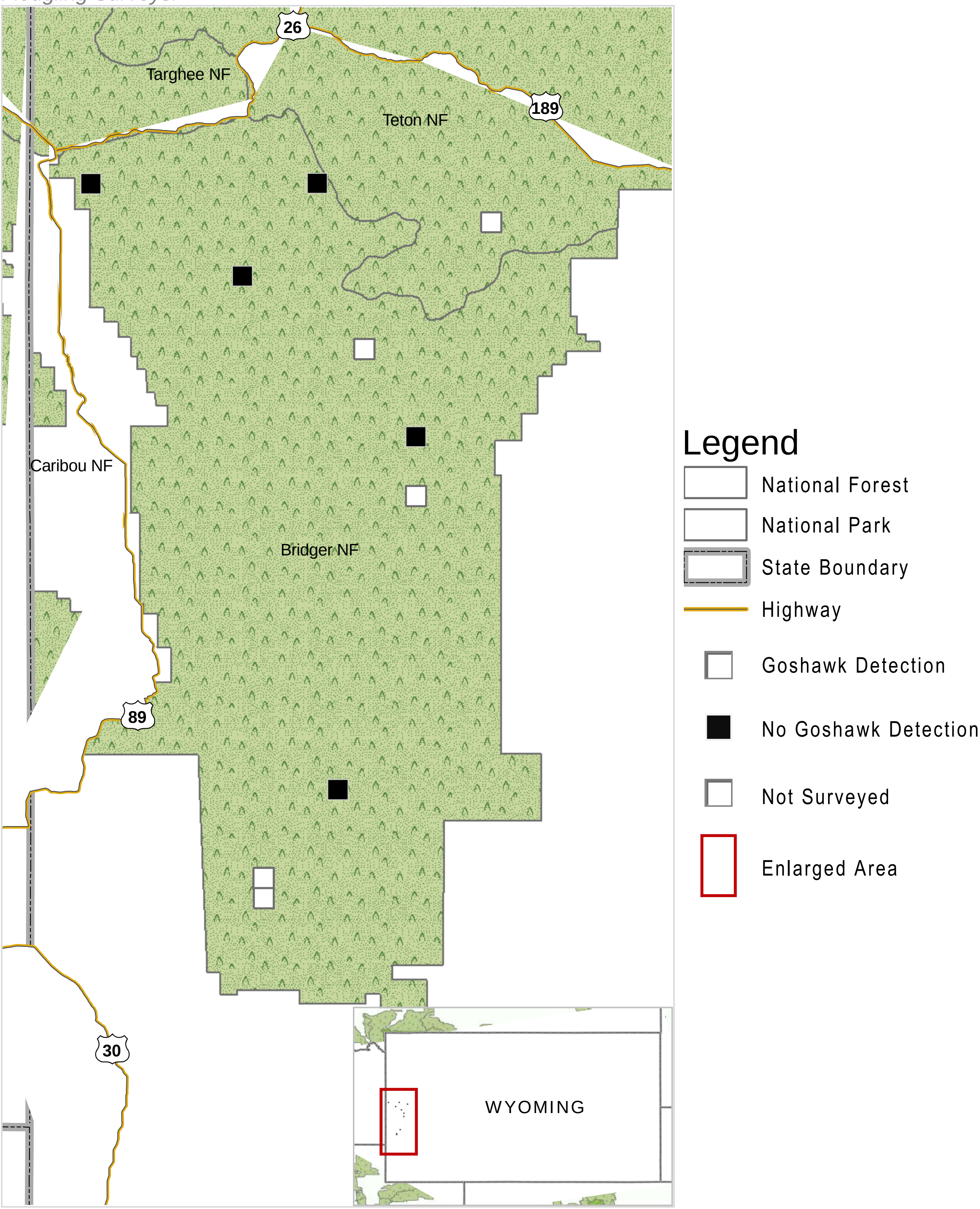


Figure 5. Probabilities of occupancy of goshawks using data from the Bridger-Teton National Forests and/or the U.S. Forest Service, Rocky Mountain Region.

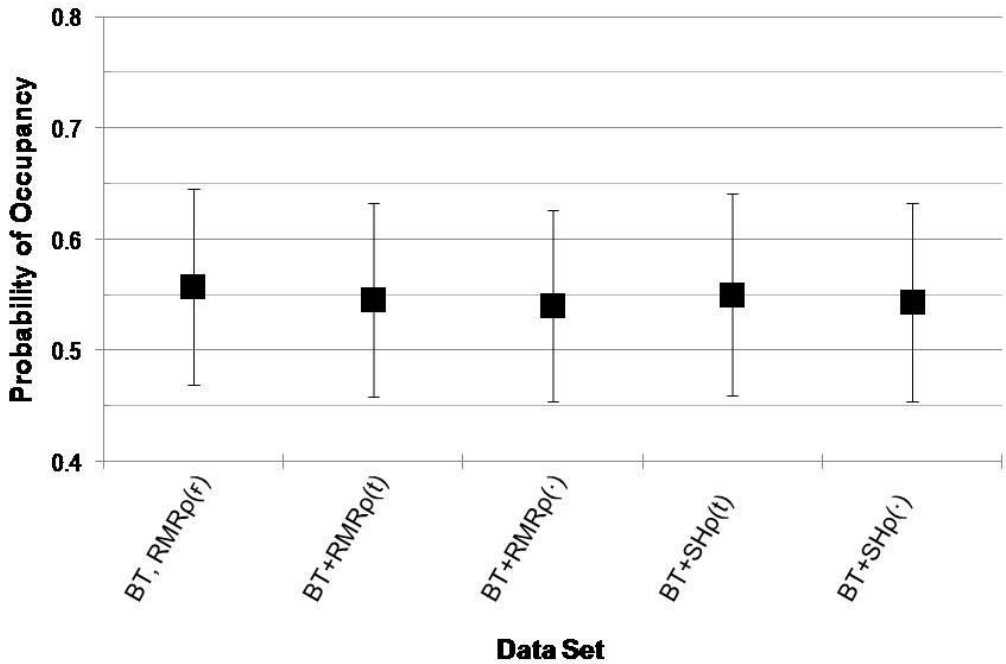
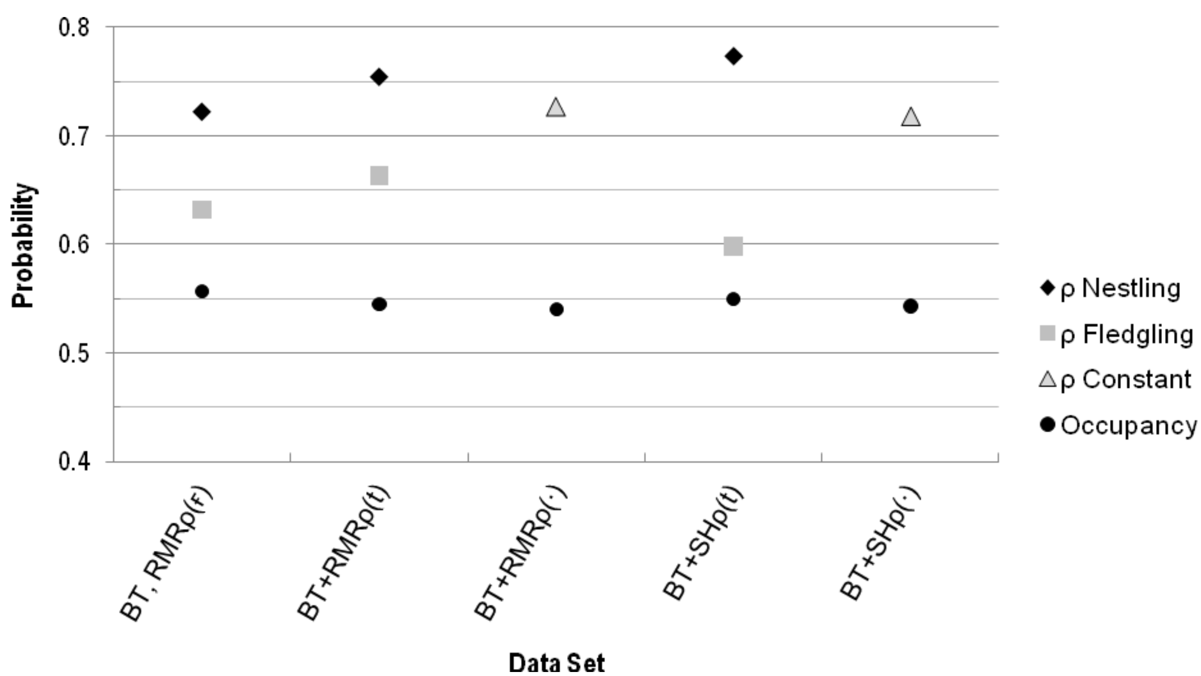


Figure 6. Occupancy and detection probabilities of goshawks using presence/absence data from the Bridger-Teton National Forests and the U.S. Forest Service Rocky Mountain Region.



APPENDIX A

List of Primary Sampling Units (PSU) surveyed with detection results for the Rocky Mountain Region, U.S. Forest Service during the 2009 season of the National Goshawk Monitoring Program.

PSU ID	Forest	State	Nestling Survey Detection	Fledgling Survey Detection
ARP877	Arapahoe	CO	N	N
ARP890	Arapahoe	CO	N	N
ARP894	Arapahoe	CO	Y	N
ARP941	Arapahoe	CO	Y	-[Φ]
ARS859	Arapahoe	CO	N	N
GMUGP2174	Grand Mesa	CO	Y	-
GMUGP2297	Grand Mesa	CO	Y	Y
GMUGP2814	Gunnison	CO	N	Y
GMUGP2852	Gunnison	CO	Y	-
GMUGS2246	Gunnison	CO	N	N
GMUGS2324	Gunnison	CO	N	N
GMUGS2336	Gunnison	CO	Y	N
GMUGS2343	Gunnison	CO	N	Y
GMUGS2506	Gunnison	CO	-	N
GMUGS2552	Gunnison	CO	N	N
GMUGS2702	Gunnison	CO	-	Y
PSIP1170	Pike	CO	Y	N
PSIP1185	Pike	CO	Y	-
PSIS1085	Pike	CO	N	N
PSIS1097	Pike	CO	N	N
PSIS1107	Pike	CO	N	N
PSIS1124	Pike	CO	N	N
RGP2147	Rio Grande	CO	N	N
RGS1712	Rio Grande	CO	-	N
RGS1767	Rio Grande	CO	N	N
RGS1804	Rio Grande	CO	-	N
RGS1860	Rio Grande	CO	N	N
RGS1902	Rio Grande	CO	N	N
RGS1969	Rio Grande	CO	N	N
RGS1989	Rio Grande	CO	N	-
RGS2002	Rio Grande	CO	Y	N
RGS2009	Rio Grande	CO	Y	N
RTP3539	Routt	CO	Y	Y
RTP3571	Routt	CO	Y	-
RTP3572	Routt	CO	Y	Y
RTP3607	Routt	CO	Y	-

PSU ID	Forest	State	Nestling Survey Detection	Fledgling Survey Detection
RTP3615	Routt	CO	N	N
RTS3705	Routt	CO	N	N
RTS3806	Routt	CO	N	N
RTS3830	Routt	CO	N	Y
RTS3862	Routt	CO	N	N
RTS3873	Routt	CO	N	N
RTS3938	Routt	CO	Y	-
SJP1311	San Juan	CO	N	N
SJP1592	San Juan	CO	N	N
SJS1211	San Juan	CO	N	N
SJS1221	San Juan	CO	N	Y
SJS1287	San Juan	CO	N	N
SJS1294	San Juan	CO	Y	Y
SJS1324	San Juan	CO	-	N
SJS1330	San Juan	CO	N	N
SJS1452	San Juan	CO	N	N
SJS1481	San Juan	CO	N	N
SJS1527	San Juan	CO	N	N
SJS1627	San Juan	CO	N	N
GMUGP2600	Uncompahgre	CO	Y	Y
GMUGP2834	Uncompahgre	CO	N	-
GMUGS2778	Uncompahgre	CO	N	N
WRP3210	White River	CO	Y	Y
WRS2926	White River	CO	Y	Y
WRS3013	White River	CO	N	N
WRS3090	White River	CO	N	N
WRS3113	White River	CO	N	N
WRS3131	White River	CO	N	N
WRS3170	White River	CO	Y	Y
WRS3188	White River	CO	N	N
BHP3963	Black Hills	SD	Y	-
BHP3975	Black Hills	SD	Y	N
BHP3979	Black Hills	SD	N	Y
BHP4026	Black Hills	SD	N	N
BHP4034	Black Hills	SD	Y	-
BHP4044	Black Hills	SD	N	N
BGHD4364	Big Horn	WY	N	N
BGHP4164	Big Horn	WY	Y	Y
BGHP4230	Big Horn	WY	Y	Y
BGHP4304	Big Horn	WY	Y	-
BGHP4355	Big Horn	WY	Y	-

PSU ID	Forest	State	Nestling Survey Detection	Fledgling Survey Detection
BGHP4376	Big Horn	WY	N	Y
BGHP4383	Big Horn	WY	Y	Y
BGHP4419	Big Horn	WY	Y	-
BGHP4423	Big Horn	WY	N	Y
BGHP4436	Big Horn	WY	Y	-
BGHS4088	Big Horn	WY	Y	-
BGHS4103	Big Horn	WY	Y	Y
BGHS4232	Big Horn	WY	N	N
MBP3347	Medicine Bow	WY	Y	-
MBP3366	Medicine Bow	WY	Y	-
MBP3399	Medicine Bow	WY	N	N
MBP3432	Medicine Bow	WY	N	N
MBP3454	Medicine Bow	WY	Y	-
MBP3461	Medicine Bow	WY	Y	-
MBP3463	Medicine Bow	WY	N	Y
MBP3468	Medicine Bow	WY	Y	-
MBP3509	Medicine Bow	WY	Y	Y
MBS3260	Medicine Bow	WY	N	N
MBS3311	Medicine Bow	WY	N	N
MBS3326	Medicine Bow	WY	N	N
SHP445	Shoshone	WY	N	N
SHP454	Shoshone	WY	Y	N
SHP550	Shoshone	WY	Y	-
SHP637	Shoshone	WY	Y	-
SHP728	Shoshone	WY	N	Y
SHP752	Shoshone	WY	Y	N
SHS137	Shoshone	WY	N	N
SHS196	Shoshone	WY	N	Y
SHS517	Shoshone	WY	-	Y
SHS644	Shoshone	WY	Y	-
SHS676	Shoshone	WY	-	N
SHS765	Shoshone	WY	N	N

[Φ] – PSU not completed during survey.