

Northern Goshawk Monitoring in the Apache-Sitgreaves National Forests: 2014 Field Season Report



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EXECUTIVE SUMMARY

The Northern Goshawk (*Accipiter gentilis*; goshawk) is the largest accipiter found in North America and inhabits much of the forested land in the United States. Because the bird's primary habitat is forested land, much of the bird's range falls within U.S. Forest Service's (USFS) administrative boundaries in the lower 48 states. However, very little is actually known about the bird's population across large spatial extents. The Northern Goshawk has been defined as a sensitive species by the USFS and is a potential candidate to be listed under the Threatened and Endangered Species Act. These concerns and classifications lead to the publication of the "Northern Goshawk Inventory and Monitoring Technical Guide" (Woodbridge and Hargis 2006) by the USFS to aid regional managers as well as local officials to develop and implement regional monitoring of Northern Goshawk populations. Through the use of presence/absence surveys, the guide outlines how occupancy modeling can be used to determine goshawk population status and trends.

The USFS contracted Rocky Mountain Bird Observatory (RMBO) to assist in the development and implementation of Northern Goshawk monitoring using the technical guide as a reference. In 2013, a grid of 1,481 600-ha Primary Sampling Units (PSU) was laid across the Apache-Sitgreaves National Forests in Arizona. Each PSU was delineated into one of three strata based on information from the Apache-Sitgreaves cover-type and the Wallow Fire burn intensity data layer. We stratified the grid cells within the administrative boundary according to pinyon-juniper woodland and subalpine forests, ponderosa pine forest and ponderosa pine forest within the Wallow Fire burn perimeter. Sampling units were selected with a spatially balanced design using the Generalized Random Tessellation Stratified (GRTS) function (Spsurvey package) in R.

Broadcast acoustical surveys were conducted in the selected sampling units during two time periods (nestling and fledgling) in the summers of 2013 and 2014. We completed a 100 percent re-sample effort; all 21 PSUs surveyed in 2013 were surveyed again in 2014. We surveyed all PSUs twice in 2014, once between 1 June and 6 July and again between 7 July and 20 August 2014. Four PSUs had goshawk detections during the nestling period and two PSUs had goshawk detections during the fledgling period.

We used 12 combinations to determine detection probability and occupancy estimates by combining four models for detection probability and three models for occupancy and evaluated each model for best fit with Akaike's information criterion corrected for small sample size (AICc). The occupancy model with the lowest AICc value used a constant rate of detection across strata, season and year and included the year effect on occupancy. The forest-wide detection probability was 0.342 (SE = 0.173) and occupancy was 0.563 (CI: 0.162 - 0.896) in 2013 and 0.445 (CI: 0.131 – 0.809) in 2014.

The 2014 occupancy estimates indicate there was a higher density of goshawks in the Apache-Sitgreaves National Forests in 2013 and 2014 than in the USFS Southwest Region in 2009 ($\psi = 0.286$; CI: 0.154-0.357). 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 and years. We achieved this initial comparison by determining status and a trend between the 2013 and 2014 Northern Goshawk population estimates in the Apache-Sitgreaves National Forests. There was some evidence for a 21% decline ($\hat{\lambda}_{\psi_{ij}} = 0.79$; CI: 0.00, 1.00), although the estimate's precision suggests there was no change in occupancy.

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Elizabeth Humphrey of the United States Forest Service was essential in the development and funding of this monitoring effort. Staff within Rocky Mountain Bird Observatory provided input, expertise, services and support including Rob Sparks, who created the GIS sampling frame and completed the sample selection. Of course field studies could not be completed without field staff. These individuals, Tyler Files, Carson Lillard, David Meyer, and Melissa Thompson not only completed the tasks set before them, but completed their work with enthusiasm, eagerness and attention to detail. Finally, this report benefitted greatly from peer reviews by Matthew McLaren and Chris White.

TABLE OF CONTENTS

Executive Summary	i
Acknowledgements	ii
Table of Contents	iii
Tables & Figures	iv
Introduction	1
Methods	3
Study Area	3
Field Personnel	4
Sampling Unit Selection	4
Survey Protocol.....	6
Sampling Design.....	6
Occupancy estimation.....	7
Model Selection and Model Averaging	7
Climate.....	8
Results	8
Discussion and Recommendations	14
Literature Cited	17
Appendix A	19

TABLES & FIGURES

Table 1. Stratification of sampling grids with the number of grids allocated to each stratum.....	4
Table 2. Primary Sampling Units (PSUs) sampled in the Apache-Sitgreaves National Forests during the 2014 field season, allocated to strata. All PSUs were surveyed twice.....	8
Table 3. Total Northern Goshawk (<i>Accipiter gentilis</i>) detections in the Apache-Sitgreaves National Forests, June-August, 2014.....	9
Table 4. Model selection for estimating the detection and occupancy rates of the Northern Goshawk (<i>Accipiter gentilis</i>) in the Apache-Sitgreaves National Forests, Arizona, USA, 2013 - 2014. The model selection metrics are the number of parameters (K), minimized $-2 \log$ -likelihood of the model $[-2\log(L)]$, Akaike Information Criterion adjusted for sample size (AIC_c), change in AIC_c (ΔAIC_c) and AIC_c weight (w_i).....	11
Table 5. Model averaged estimates of the probability of detection, unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk (<i>Accipiter gentilis</i>) in the Apache-Sitgreaves National Forests, Arizona, USA, 2013-2014.....	11
Table 6. Combined model averaged estimates of the probability of detection, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2014.....	12
Table 7. Model averaged estimates of the probability of occupancy, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2014.....	12
Table 8. Combined model averaged estimates of the probability of occupancy, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2014.....	12
Figure 1. Classification of suitable habitat for the Northern Goshawk (<i>Accipiter gentilis</i>) in the Apache-Sitgreaves National Forests, Arizona, 2013 - 2014.....	3
Figure 2. An example of a Primary Sampling Unit (PSU) map used by technicians throughout the field season to survey for Northern Goshawks (<i>Accipiter gentilis</i>) in the Apache-Sitgreaves National Forests, Arizona, 2014.....	5
Figure 3. Primary Sampling Units (PSUs) surveyed for Northern Goshawks (<i>Accipiter gentilis</i>) in the Apache-Sitgreaves National Forests, June-August, 2013 and 2014.....	9
Figure 4. Surveyed Primary Sampling Units (PSUs) in the Apache-Sitgreaves National Forests with Northern Goshawk (<i>Accipiter gentilis</i>) detections, June-August, 2014.....	10
Figure 5. Average monthly temperatures for 2013 and 2014 compared to the 30-year average. Payson, Arizona.....	13
Figure 6. Total monthly precipitation for 2013 and 2014 compared to the 30-year average. Payson, AZ.....	13
Figure 7. Occupied Northern Goshawk (<i>Accipiter gentilis</i>) Primary Sampling Units (PSU) surveyed in 2013 and 2014 and Wallow Fire burn intensity (based on basal area loss).....	15

INTRODUCTION

The Northern Goshawk (*Accipiter gentilis*, goshawk) is the largest of three accipiters found in North America (Squires and Reynolds 1997). Goshawks inhabit and nest in several types 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 is dependent on the local forest types. For example, goshawks are known to 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, goshawks generally show a preference for large, mature tree stands for nesting as well as a need for a sufficient prey base to maintain population stability (Reynolds et al. 1992, Anderson et al. 2005). Because goshawks generally require 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).

Goshawk population estimates are undetermined across vast areas because of difficulties associated with the low density of goshawks (≤ 12 nesting pairs/100-km²) mixed with the bird's cryptic behavior (Squires and Reynolds 1997). Therefore, the overall status of the Northern Goshawk's population remains unknown (Anderson et al. 2005, Woodbridge and Hargis 2006).

The Northern Goshawk is protected by several laws and regulations both within the U.S. Forest Service (USFS) and broader intra-agency guidance, including the Migratory Bird Treaty Act of 1916; Executive Order 13186 (01-10-2001), "Responsibilities of Federal Agencies to protect Migratory Birds" (1991) and its associated Memorandum of Understanding between the USFS and the US Fish & Wildlife Service (FWS); the USFS Landbird Strategic Plan of 2001; the USFS sensitive species program - FSM R-3 Supplement 2676.3 (United States Forest Service 1995); and the National Forest Management Act of 1976 (Woodbridge and Hargis 2006). Furthermore, public involvement resulted in a petition to the FWS for federal listing of the Northern Goshawk in the Western United States in 1997 (United States Fish and Wildlife Service 1998). The FWS deemed the listing of the Northern Goshawk as threatened or endangered as unwarranted after a 12-month review because there was no evidence that Northern Goshawk populations were declining (United States Fish and Wildlife Service 1997). However, the inquiry also found that there was an overall lack of data of Northern Goshawk population status and trend and therefore, it was also unknown if populations were increasing or stable. This interest in the Northern Goshawk population assessment culminated with the creation of the USFS's "Northern Goshawk Inventory and Monitoring Technical Guide" (Woodbridge and Hargis) in 2006 to establish a protocol to survey national forests within all USFS administrative regions within the Northern Goshawk's geographic range.

The Apache-Sitgreaves National Forests contracted Rocky Mountain Bird Observatory (RMBO) to develop and implement Northern Goshawk monitoring, using the technical guide as a reference. The contract between these two entities was advantageous for the National Forest because RMBO has already completed goshawk monitoring efforts for the U.S. Forest Service's Southwest Region in forests throughout Arizona and New Mexico (United States Forest Service, Southwest Region. 2012a).

The Apache-Sitgreaves National Forests encompasses over two million acres of forests and woodlands in Arizona (United States Forest Service 2009). The forest is included in the Northern Goshawk's breeding range; therefore, the administrative region is responsible to assess and document the effects of proposed management actions on Northern Goshawk

populations as required by the USFS sensitive species program. Several forests within the region have conducted localized and individualized surveys of goshawks, including one of the most extensively studied populations in the Kaibab National Forest (Reynolds et al. 1992, Squires and Reynolds 1997, Reynolds and Joy 1998, Reich et al. 2004, Reynolds et al. 2008). Although this research is consistently carried out within a relatively small area and provides useful information on local Northern Goshawk populations, the information cannot be compared with other forests' data if differences in monitoring protocols and methods exist.

In 2009, the first large-scale surveys were conducted within the Southwest Bioregion. RMBO determined a detection probability of 0.448 (SE = 0.155) and occupancy estimate of 0.286 (CI: 0.154-0.357) for the area (Berven 2010). The 2009 bioregional effort also addressed the question of pinyon-juniper woodland use by nesting goshawks. Researchers speculate that the birds do not use the woodlands for nesting, or only use the woodlands in years when an exceptionally high prey base can support a larger Northern Goshawk population and less dominant goshawks are pushed to the woodlands only when all ponderosa pine or mixed coniferous habitat has been territorialized (Reynolds et al. 1992, Drennan and Beier 2003, Reynolds et al. 2008). In the 2009 study, RMBO estimated an occupancy of 0.473 (confidence interval (CI): 0.262 – 0.693) for ponderosa pine and mixed coniferous forests in the Southwest bioregion and 0.122 (CI: 0.048 – 0.274) for pinyon-juniper woodlands (Berven 2010). These results indicate that, although goshawks show a preference for ponderosa pine and mixed coniferous forests, pinyon-juniper woodlands are occupied to some extent and cannot be excluded from the monitoring effort.

Monitoring Northern Goshawk populations is a challenging endeavor due to the cryptic nature of the bird, low population densities and the rugged terrain associated with the bird's habitat (Woodbridge and Hargis 2006). Therefore, occupancy is the preferred method to assess status and changes in Northern Goshawk populations from year to year without the need for extensive abundance surveys (MacKenzie and Nichols 2004, Woodbridge and Hargis 2006). 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. Occupancy can be used as a surrogate for abundance because the two are positively correlated (MacKenzie and Nichols 2004).

While bioregional monitoring can evaluate trends and bird responses over a large area, the effort is expensive and completed infrequently. Furthermore, local managers may have specific questions about their forests that cannot be answered at the bioregional scale. The Apache-Sitgreaves National Forests provide such an example with the Wallow Fire of 2011. The Wallow fire started on 29 May, 2011 and burned over 535,000 acres. Over 500,000 acres were within the National Forest boundary and almost 120,000 acres of ponderosa pine and mixed coniferous forests were moderately to severely burned (Wadleigh 2011). Wildlife managers asked the questions; what is the current status of Northern Goshawk populations in the Apache-Sitgreaves National Forests and what is the effect of the Wallow Fire on goshawk occupancy two years after a large and destructive fire? RMBO's current monitoring effort within the Apache-Sitgreaves National Forest can simultaneously address both questions by stratifying areas of interest based on habitat and where the fire burned. However, the ultimate goal should be to monitor the population over an extended period of time to fully understand occupancy trends and use of burned areas.

METHODS

Study Area

The study area encompasses all Forest Service lands located in the Apache-Sitgreaves National Forests in Arizona that include potential Northern Goshawk habitat (Figure 1).

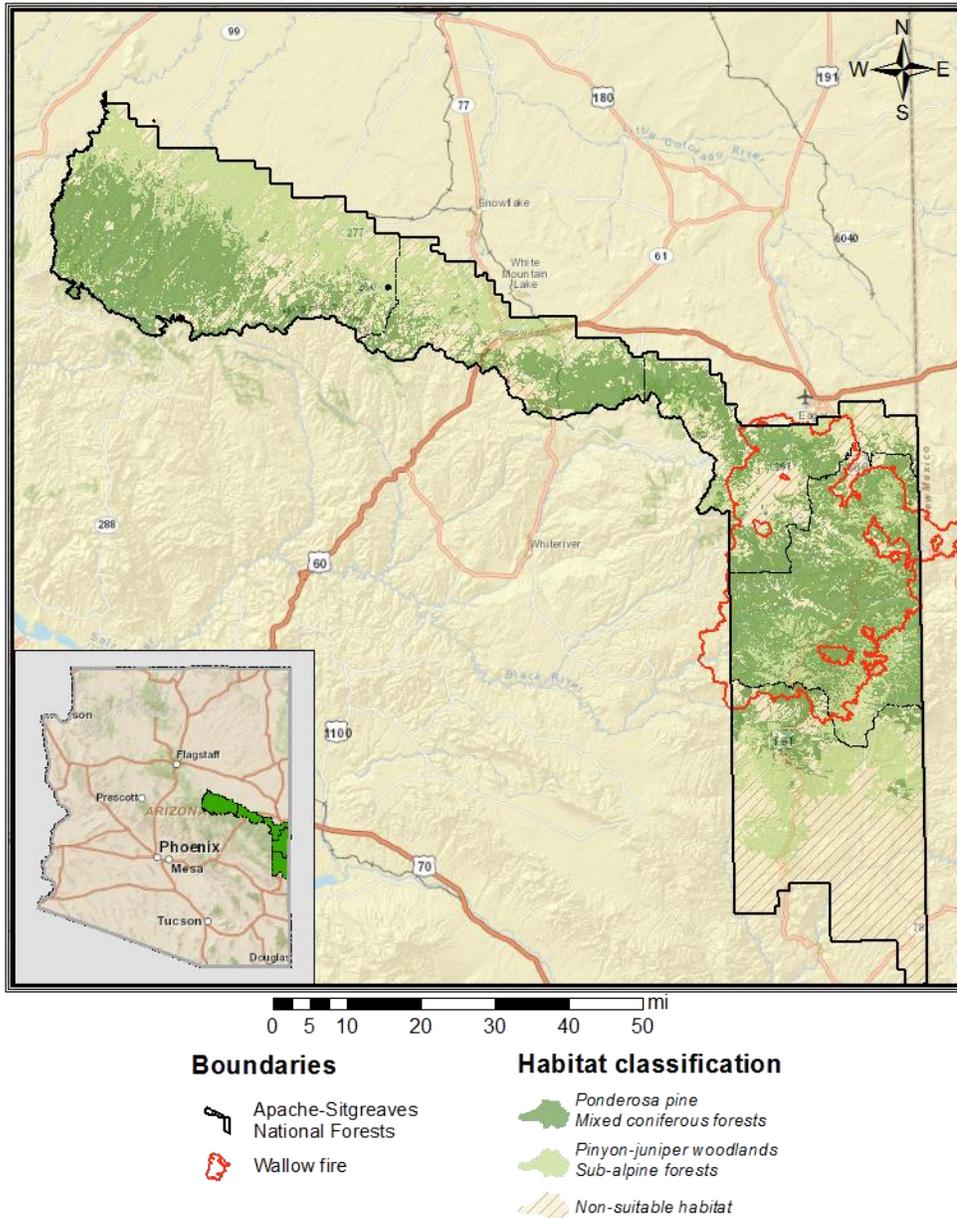


Figure 1. Classification of suitable habitat for the Northern Goshawk (*Accipiter gentilis*) in the Apache-Sitgreaves National Forests, Arizona, 2013 - 2014.

Field Personnel

Biological field technicians who had previous field experience working with Northern Goshawks, including knowledge of the species' 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 individuals with less avian field experience. For all individuals, experience hiking in remote areas and a good work ethic were required.

All technicians received training in Northern Goshawk identification. Training emphasized identification by visual and aural cues, feathers and nest presence. We also trained technicians extensively in survey and data collection protocol. The training was conducted by RMBO personnel in the last week of May 2014.

Sampling Unit Selection

We selected and surveyed the same sampling units for the 2014 field season as we did for the 2013 field season. In 2013, Primary Sampling units (PSUs) were created and selected using protocols delineated in the “Northern Goshawk Inventory and Monitoring Technical Guide” (Woodbridge and Hargis 2006). Using ArcGIS (Kullback and Leibler 1951), a region-wide grid was created by overlaying 600 ha PSUs onto a USFS administrative border layer. We defined the sampling frame as the set of PSUs containing a minimum of 20% potential Northern Goshawk habitat using the Apache-Sitgreaves cover layer. We stratified the grid cells within the administrative boundary according to marginal habitat (pinyon-juniper woodland and subalpine forests; $n = 383$; Table 1), and primary habitat (ponderosa pine forest and mixed conifer) inside ($n = 293$) and outside ($n = 489$) of the Wallow Fire burn using the Apache-Sitgreaves cover-type and Wallow Fire burn intensity (Table 1) data layers (United States Forest Service. Southwest Region. 2011, 2012a).

Table 1. Stratification of sampling grids with the number of grids allocated to each stratum.

	Unburned	Burned	Total
Primary - Ponderosa pine and mixed coniferous	489	293	782
Marginal - Pinyon-juniper woodland and subalpine	383	-	383
Total	872	293	1,165

A spatially balanced study design was implemented to order PSUs within the Apache-Sitgreaves National Forests by using the generalized random-tessellation stratification (GRTS) function (Spsurvey package) in R (Stevens 2004). After the PSUs were randomly selected for survey, a grid of call station points was added to each unit using ArcGIS. For PSUs located completely within the USFS Administrative boundary, 120 call stations on 10 transect lines (each containing 12 stations spaced 200 m apart) were overlaid on the PSU (Figure 2). Each transect line was placed 250 m apart and located at least 150 m from the PSU border. Call stations on adjacent transect lines were vertically offset by 100 m. For PSUs located on the perimeter of the USFS Administrative boundary, the call station grid was overlaid onto border PSUs as if the PSU was unclipped but all call stations outside of Forest Service land were removed from the survey effort. Call stations in unsuitable locations (slope $>36^\circ$, >150 m away from forest cover or on private land) were identified using ArcGIS. We used a 30 x 30 m LANDFIRE slope layer (2004) to identify call stations located in areas that were too steep to survey. We used the Apache-Sitgreaves cover-type layer (United States Forest Service 2012)

to identify call stations >150 m from tree cover. We identified and labeled call stations located on private land using the USFS Surface Ownership layer (United States Forest Service, Southwest Region, 2012b). All call stations within the administrative boundary were included on maps but were labeled according to suitability criteria (Figure 2).

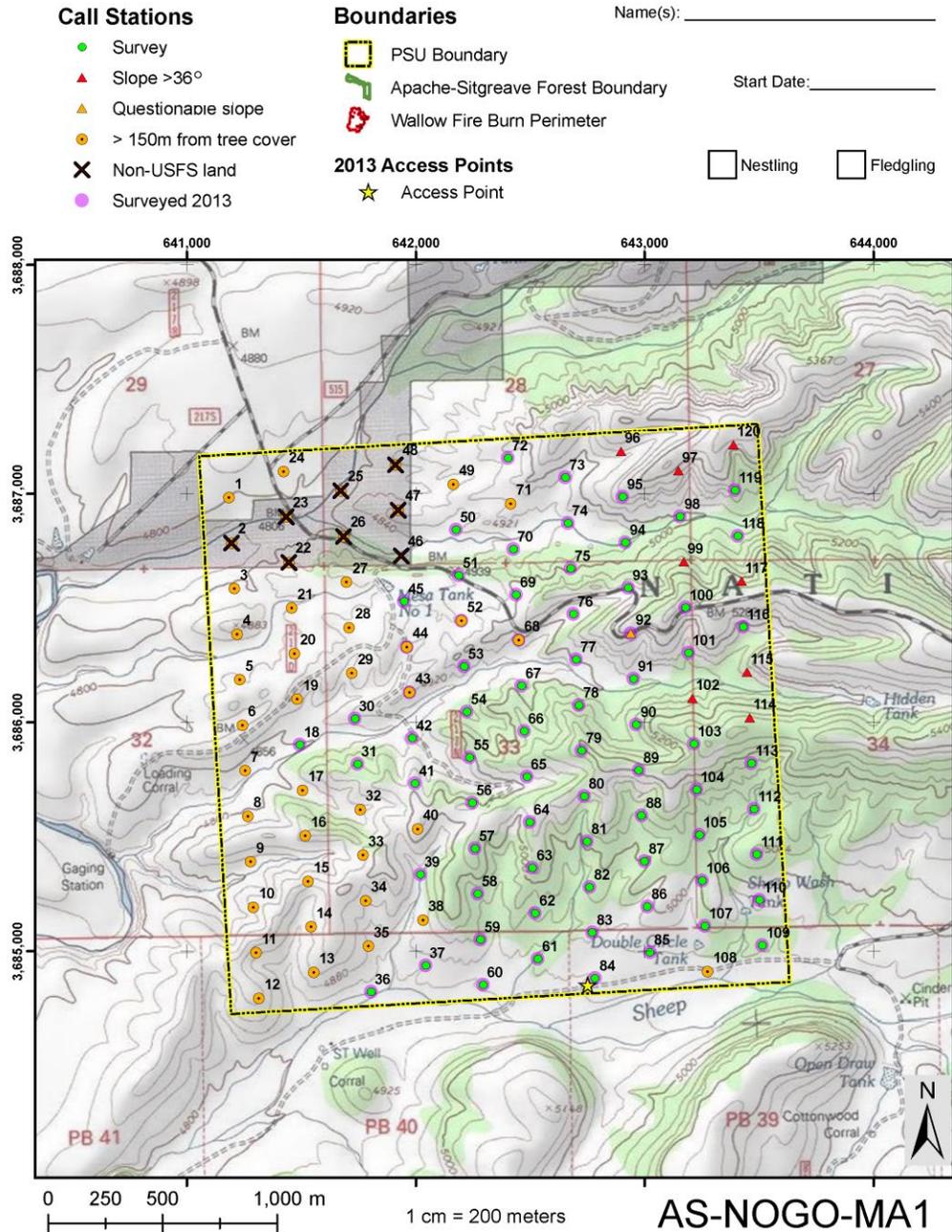


Figure 2. An example of a Primary Sampling Unit (PSU) map used by technicians throughout the field season to survey for Northern Goshawks (*Accipiter gentilis*) in the Apache-Sitgreaves National Forests, Arizona, 2014.

Using ArcGIS, field maps were created showing PSU and study area boundaries and call stations were overlaid onto 1:24,000-scaled topographic maps (ESRI 2011). Maps were scaled to 1:20,000 to simplify navigation between call stations.

Survey Protocol

We used the “Northern Goshawk Inventory and Monitoring Technical Guide” (Woodbridge and Hargis 2006) to define survey protocols. Technicians conducted broadcast acoustical surveys during the nestling and fledgling periods of the Northern Goshawk breeding season.

Technicians made two visits 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 beginning of July through August 15; however, to maximize detectability of goshawks in the region, we received input from district USFS biologists and other scientists monitoring goshawk nests throughout the region to specify when eggs were expected to hatch. The nestling surveys ended once all planned PSUs were surveyed once - this occurred before nestlings began to fledge. The fledgling surveys 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.

Broadcast acoustical surveys could be conducted anytime between 30 minutes before sunrise through 30 minutes before sunset, coinciding with goshawk activity (Woodbridge and Hargis 2006). However, most surveys were conducted between 0830 and 1600 Mountain Standard Time. Calling procedure followed protocols described in the monitoring technical guide (Woodbridge and Hargis 2006). Technicians broadcast one of three Northern Goshawk calls depending on whether it was during the nestling or fledgling survey. During the nestling survey, an adult alarm call was broadcast and during the fledgling survey, a juvenile food-begging call or a wail call was broadcast. Technicians used FoxPro NX3 digital callers preloaded with the calls at a volume producing 80 to 110 dB output 1 m from the speaker.

At each call station, technicians played one call for 10 seconds, then watched and listened for Northern Goshawk activity for 30 seconds then repeated the procedure after rotating 120 degrees. Once this procedure was done 3 times (and the circle completed), technicians waited, watched and listened for 2 minutes then repeat the cycle. Technicians recorded any significant findings and time spent at each call station on a standardized field form. After 2 full rounds of playing the call, technicians 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 Northern Goshawk detection was made within a PSU boundary. A positive detection consisted of a visual or aural observation or finding an active nest. If a bird was seen, sex and age were recorded, if known. Compass bearing of a bird's approach and departure, station number and distance from the point of detection were also recorded. Aural detections were followed by an attempt to get a visual of the bird to determine age and sex.

Sampling Design

The schedule of repeated surveys of the PSUs corresponded to a double sampling design with two survey occasions (MacKenzie et al. 2006). In 2013, we conducted repeat surveys for all PSUs with no detections during the first occasion and we conducted repeat surveys for a random sample of PSUs with detections during the first occasion. In 2014, we used the

standard sampling design where all PSUs received a second visit because of low detection rates during the nestling season.

Occupancy estimation

We estimated the probability of Northern Goshawk occupancy within the Apache-Sitgreaves National Forest using the MacKenzie et al. (2002) occupancy model. We used program MARK for parameter estimation (MARK Version 6.1, www.phidot.org, accessed 21 December 2014), and the R package RMark for model construction (RMARK Version 2.1.7, accessed 23 January 2015; R Version 3.0.2, www.R-project.org, accessed 23 January 2015). We estimated the probability of occupancy separately for each stratum (pinyon-juniper woodland, ponderosa pine forest, burned ponderosa pine forest). We evaluated 4 models for estimating the probability of detection, including a model that held the detection probability constant [$p(\cdot)$], and models that allowed detection to vary by season (nesting and fledging periods) [$p(t)$], strata [$p(\text{stratum})$] and survey effort [$p(\text{effort})$]. We measured survey effort as the percentage of available call station points within the PSUs ($\bar{x} = 74\%$, $SD = 27\%$, range = 9%, 100%). We evaluated three models for the probability of occupancy, including a model that allowed occupancy to vary by year [$\psi(\text{year})$], stratum [$\psi(\text{stratum})$] and the interaction between year and stratum [$\psi(\text{year}*\text{stratum})$]. Because no Northern Goshawks were detected in the Pinyon-Juniper stratum, we fixed detection to one and occupancy to zero for this stratum, and analyzed the data using only data from the Burned Ponderosa Pine and Ponderosa Pine strata.

We estimated Northern Goshawk occupancy and detection for the Apache-Sitgreaves National Forest using the mean of the estimates weighted by strata area. For example, the occupancy rate for the Apache-Sitgreaves National Forest was estimated by $\hat{\Psi}_{\text{Forest}} = \sum_{i=1}^3 w_i \hat{\Psi}_i$, where the number of strata was 3, the weight w_i was the proportion of PSUs in stratum i , and $\hat{\Psi}_i$ was the estimated probability of occupancy for stratum i . We approximated sampling variances and standard errors for the estimates using the delta method (Powell 2007) (R Version 2.15.2). Our application of the delta method estimated the standard errors of the occupancy estimates by accounting for the covariance between the stratum-specific estimates (Powell 2007). We estimated asymmetric 95% confidence intervals for the occupancy and detection estimates by back-transforming the logit confidence limits.

We estimated the annual trend in the occupancy rates ($\hat{\lambda}_{\psi_{ij}}$) of the Northern Goshawk in the Apache-Sitgreaves National Forest using the equation $\hat{\lambda}_{\psi_{ij}} = \frac{\hat{\Psi}_j}{\hat{\Psi}_i}$, where i represented the estimate for 2013 and j represented the estimate for 2014 (Yoccoz et al. 2001). We approximated sampling variances and standard errors for the trend using the delta method (Powell 2007) (R Version 2.15.2). For example, $\hat{\lambda}_{\psi_{ij}} = 1$ represented no change, $\hat{\lambda}_{\psi_{ij}} < 1$ represented a decline and $\hat{\lambda}_{\psi_{ij}} > 1$ represented growth in the occupancy rates over the two years.

Model Selection and Model Averaging

We used information-theoretic model selection (Burnham and Anderson 2002) to estimate the relative loss of Kullback–Leibler Information (Kullback and Leibler 1951, Burnham and Anderson 2001) when models were used to approximate conceptual truth. We ranked models by the Akaike Information Criterion (Akaike 1973) adjusted for small sample size (AIC_c) (Hurvich and Tsai 1989), measured strength of evidence for alternate hypotheses by AIC_c weights (w_i) and quantified the likelihood of modeled hypotheses given the data by evidence ratios (w_i/w_j). We model averaged the predictions and parameter estimates, and estimated unconditional standard errors and 95% confidence intervals for all models in the candidate set (Burnham and Anderson 2002).

Climate

We used data from the National Climatic Data Center (NOAA) for climate comparisons. We used data from the Payson, AZ weather station to compare monthly averages for 2013 and 2014 to the thirty-year monthly averages.

RESULTS

Nestling surveys began on 1 June 2014. Hatching was estimated to have occurred late-May to early-June 2014. Northern Goshawks in monitored nests began leaving the immediate nest area on or close to 6 July 2014. Fledgling surveys began 7 July and continued until all planned PSUs were resurveyed (20 August 2014).

Twenty-one PSUs were surveyed one time (Table 2, Figure 2, Appendix A) during the nestling survey window and all PSUs were re-surveyed during the fledgling survey window due to low detection during the nestling survey window. Technicians made a total of six goshawk detections throughout the field season (Table 3, Figure 4); four during the nestling surveys and two during the fledgling surveys.

Table 2. Primary Sampling Units (PSUs) sampled in the Apache-Sitgreaves National Forests during the 2014 field season, allocated to strata. All PSUs were surveyed twice.

	Unburned	Burned	Total
Primary habitat	11	7	18
Marginal habitat	3	-	3
Total	14	7	21

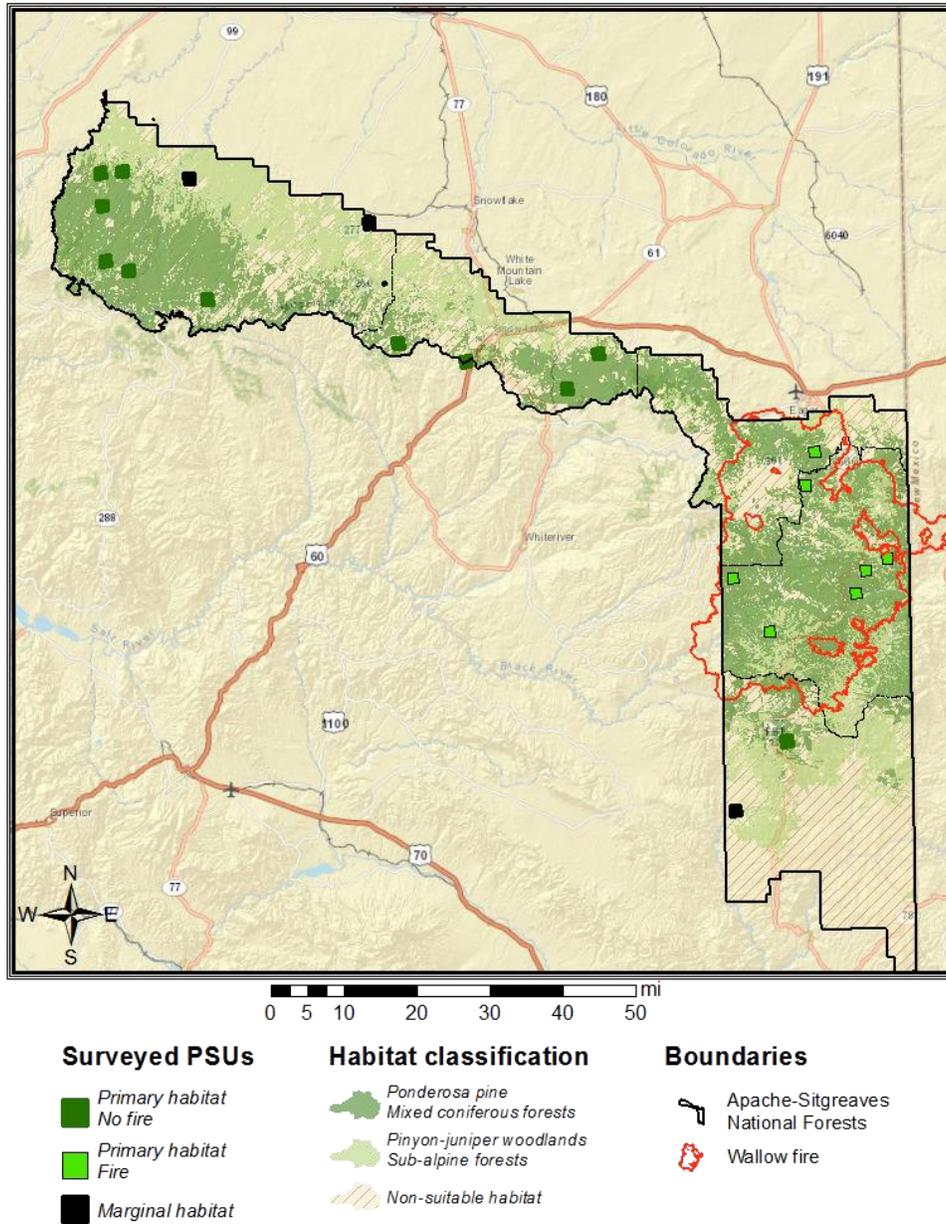


Figure 3. Primary Sampling Units (PSUs) surveyed for Northern Goshawks (*Accipiter gentilis*) in the Apache-Sitgreaves National Forests, June-August, 2013 and 2014.

Table 3. Total Northern Goshawk (*Accipiter gentilis*) detections in the Apache-Sitgreaves National Forests, June-August, 2014.

Strata	Nestling Season Detections	Fledgling Season Detections	Total
Primary - unburned	3	1	4
Primary - burned	1	1	2
Marginal habitat	0	0	0
Total	4	2	6

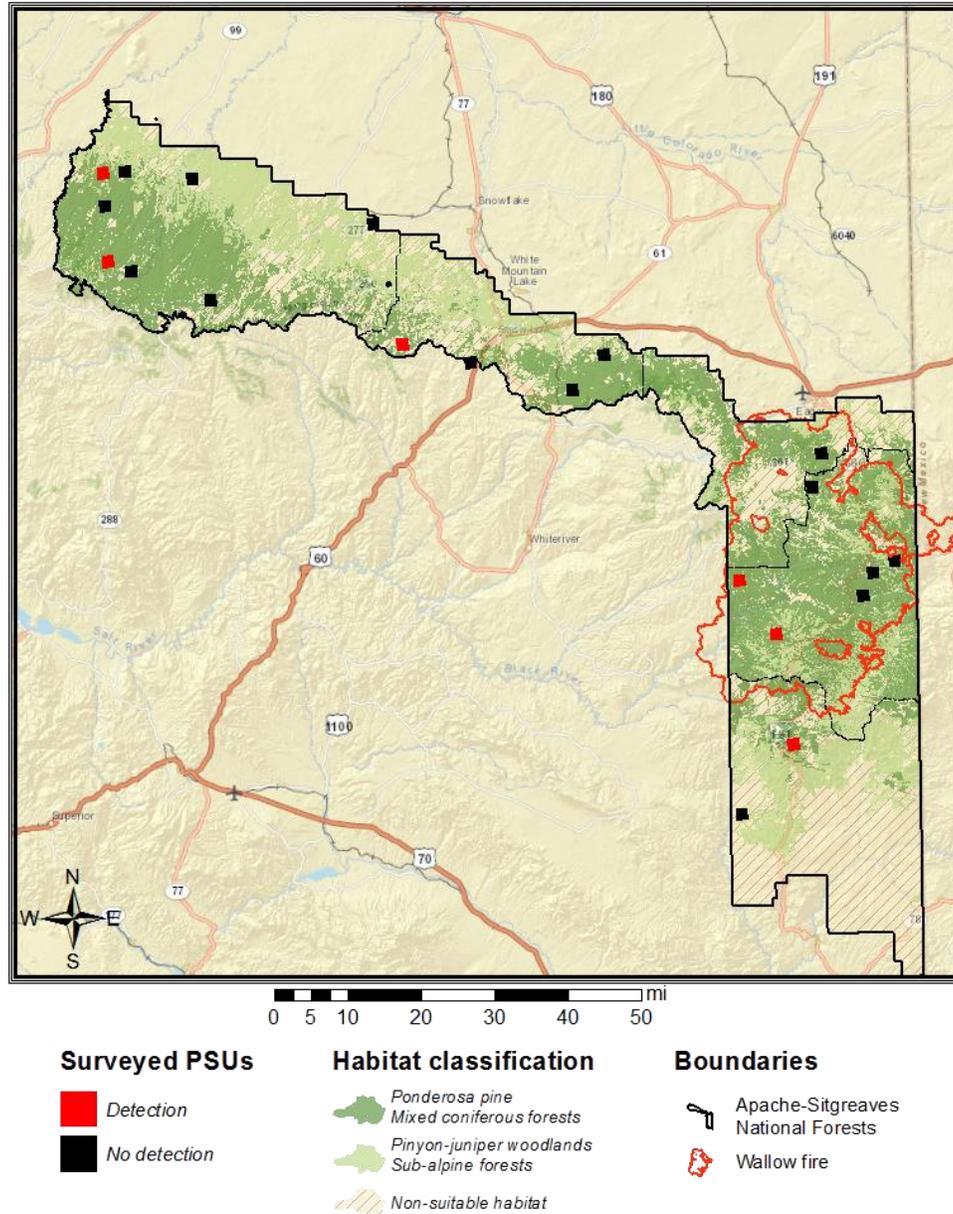


Figure 4. Surveyed Primary Sampling Units (PSUs) in the Apache-Sitgreaves National Forests with Northern Goshawk (*Accipiter gentilis*) detections, June-August, 2014.

The best approximating model for the occupancy of Northern Goshawks contained a constant rate of detection (Table 4). There was some support for the effect of nesting and fledging season in the second best model and stratum in the third best model, but the evidence ratio indicated these models were ~2 times less probable than the highest ranking model (Table 4). Results for the top three models are provided in Table 6, Table 7 and Table 8. The top two models for Northern Goshawk occupancy included the effect of year (Table 4). There was some support for the effect of stratum in the third best model, but the evidence ratio indicated the model containing the effect of stratum was ~2 times less probable than the best model containing the effect of year (Table 4). Although the year model was the best explanation for Northern Goshawk occupancy in the Apache-Sitgreaves National Forest, the 95% confidence

interval for the year effect covered 0 ($\hat{\beta} = -1.79$, SE = 3.93, CI = -9.51, 5.92) indicating a small effect size for year. Overall, there was some evidence for a 21% decline ($\hat{\lambda}_{\psi_{ij}} = 0.79$) in the occupancy rate of the Northern Goshawk in the Apache-Sitgreaves National Forest from 2013 to 2014 (Table 6). However, when considering the precision of the occupancy estimates, the trend in the occupancy rate was not different from 1 ($\hat{\lambda}_{\psi_{ij}} = 0.79$, SE = 0.80, CI = 0.00, 1.00).

Table 4. Model selection for estimating the detection and occupancy rates of the Northern Goshawk (*Accipiter gentilis*) in the Apache-Sitgreaves National Forests, Arizona, USA, 2013 - 2014. The model selection metrics are the number of parameters (K), minimized -2 log-likelihood of the model [-2log(L)], Akaike Information Criterion adjusted for sample size (AIC_c), change in AIC_c (ΔAIC_c) and AIC_c weight (w_i).

Model	K	-2log(L)	AIC_c	ΔAIC_c	w_i
$\rho(.) \psi(\text{year})$	3	75.58	82.33	0.00	0.229
$\rho(t) \psi(\text{year})$	4	74.05	83.34	1.02	0.138
$\rho(.) \psi(\text{stratum})$	3	76.60	83.35	1.02	0.138
$\rho(\text{stratum}) \psi(\text{stratum})$	4	74.13	83.43	1.10	0.133
$\rho(\text{stratum}) \psi(\text{year})$	4	74.57	83.86	1.53	0.107
$\rho(t) \psi(\text{stratum})$	4	75.07	84.36	2.04	0.083
$\rho(\text{effort}) \psi(\text{year})$	4	75.35	84.64	2.32	0.072
$\rho(\text{effort}) \psi(\text{stratum})$	4	76.34	85.64	3.31	0.044
$\rho(.) \psi(\text{year}*\text{stratum})$	5	75.01	87.01	4.69	0.022
$\rho(\text{stratum}) \psi(\text{year}*\text{stratum})$	6	72.63	87.53	5.20	0.017
$\rho(t) \psi(\text{year}*\text{stratum})$	6	73.42	88.31	5.99	0.012
$\rho(\text{effort}) \psi(\text{year}*\text{stratum})$	6	74.71	89.61	7.28	0.006

Table 5. Model averaged estimates of the probability of detection, unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk (*Accipiter gentilis*) in the Apache-Sitgreaves National Forests, Arizona, USA, 2013-2014.

Parameter	Detection Probability	SE	CV	LCL	UCL
Nesting - burned ponderosa pine	0.407	0.217	0.533	0.105	0.801
Fledging - burned ponderosa pine	0.371	0.218	0.588	0.086	0.787
Nesting - ponderosa pine	0.331	0.174	0.525	0.096	0.699
Fledging - ponderosa pine	0.295	0.158	0.537	0.085	0.651

Table 6. Combined model averaged estimates of the probability of detection, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2014.

Parameter	Detection Probability	SE	CV	LCL	UCL
Nesting	0.360	0.181	0.504	0.107	0.725
Fledging	0.323	0.172	0.532	0.092	0.691
Burned ponderosa pine	0.389	0.214	0.550	0.098	0.788
Ponderosa pine	0.313	0.163	0.522	0.093	0.669
Apache-Sitgreaves National Forest	0.342	0.173	0.507	0.102	0.702

Table 7. Model averaged estimates of the probability of occupancy, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2014.

Parameter	Occupancy Estimate	SE	CV	LCL	UCL
Pinyon-juniper - 2013	0.000	0.000	-	-	-
Pinyon-juniper - 2014	0.000	0.000	-	-	-
Burned ponderosa pine - 2013	0.804	0.396	0.493	0.029	0.999
Burned ponderosa pine - 2014	0.617	0.333	0.540	0.092	0.963
Ponderosa pine - 2013	0.859	0.370	0.430	0.014	1.000
Ponderosa pine - 2014	0.690	0.334	0.484	0.094	0.980

Table 8. Combined model averaged estimates of the probability of occupancy, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 95% confidence limits for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2014.

Parameter	Occupancy Estimate	SE	CV	LCL	UCL
Pinyon-juniper	0.000	0.000	-	-	-
Burned ponderosa pine	0.710	0.343	0.482	0.085	0.985
Ponderosa pine	0.775	0.331	0.428	0.076	0.994
Apache-Sitgreaves National Forests – 2013	0.563	0.238	0.422	0.162	0.896
Apache-Sitgreaves National Forests – 2014	0.445	0.210	0.471	0.131	0.809
Apache-Sitgreaves National Forests	0.504	0.210	0.416	0.163	0.841

We compiled climatic data from the Payson, AZ weather station for a rough comparison between the 2013 and 2014 breeding season and the 30-year average. Monthly mean temperatures indicate that 2013 was warmer from March through the end of the calendar year and 2014 maintained a fairly average temperature throughout the year (Figure 5). January 2013 was wetter than the 30-year average but remained at or below the 30-year average for the rest of the nesting season. Precipitation remained below the 30-year average for the first half of 2014.

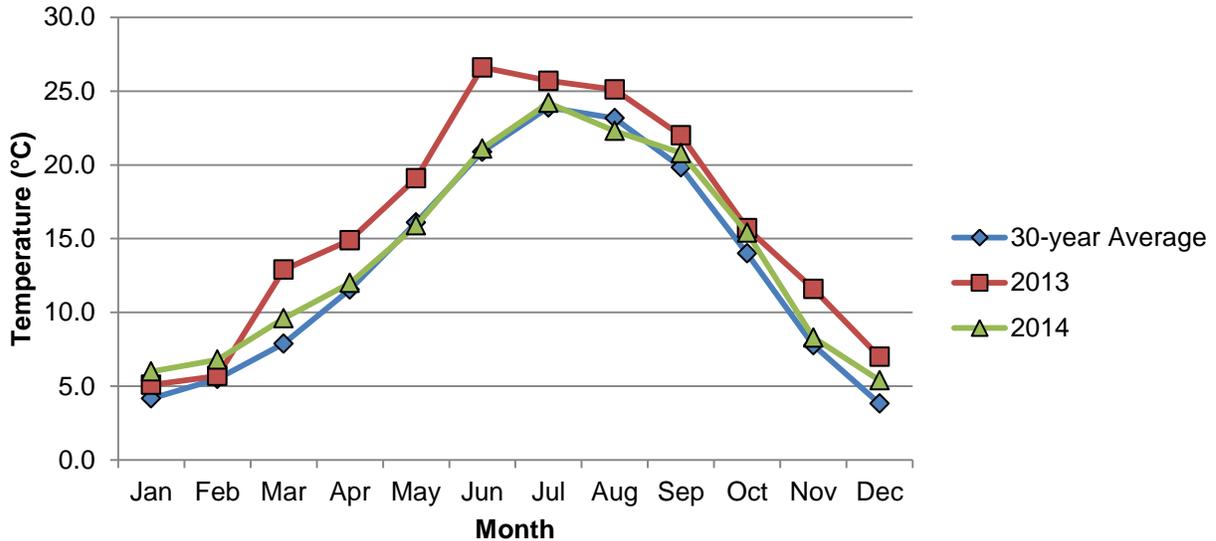


Figure 5. Average monthly temperatures for 2013 and 2014 compared to the 30-year average. Payson, Arizona.

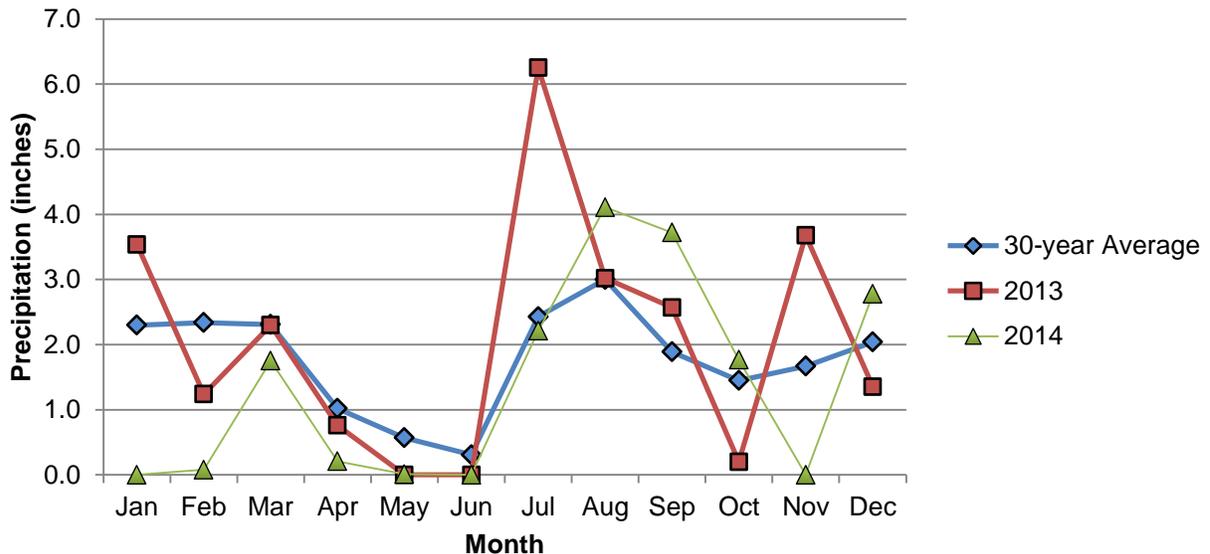


Figure 6. Total monthly precipitation for 2013 and 2014 compared to the 30-year average. Payson, AZ.

DISCUSSION AND RECOMMENDATIONS

Nationally, the status of the Northern Goshawk remains of interest because not enough is known about their population. USFS wildlife officials classified the Northern Goshawk as a species of special interest within the Southwest Region and in the Apache-Sitgreaves National Forests. The “Northern Goshawk Inventory and Monitoring Technical Guide” (Woodbridge and Hargis 2006) calls for the development and implementation of forest-level and large-scope bioregional monitoring to obtain consistent, reliable information on Northern Goshawk population status and trend and responses to management actions. The 2009 field season was the first step in accomplishing bioregional monitoring goals by creating the sampling grid, selecting PSUs based on habitat types and access and implementing the field research at a large scope. However, there remained a need to develop and implement local, smaller-scope Northern Goshawk monitoring to provide reliable data for the evaluation of the species’ status at a smaller management unit. This monitoring effort attempts to do this.

The occupancy estimates determined by the 2013 sampling effort provided a baseline status of goshawks in the Apache-Sitgreaves National Forests. In a single monitoring season, we determined that suitable habitat within the forest is a little less than half occupied by goshawks. These estimates were fine-tuned with the additional survey effort during the 2014 field season. Occupancy in the Apache-Sitgreaves National Forests in 2013 (0.563; CI: 0.162 – 0.896) and 2014 (0.445; CI: 0.131 – 0.809) was higher than occupancy in the entire Southwest Region in 2009 (0.286; CI: 0.154-0.357). However, a comparison to bioregional monitoring in a different year means little because annual goshawk breeding success varies significantly among years (Reich et al. 2004, Patla 2005, MacKenzie et al. 2006) – which was evident between the 2013 and 2014 Apache-Sitgreaves monitoring efforts. The bioregional methodology and analyses were also different from current forest-scale methodology and analyses. Therefore, the best practice is to continually and consistently monitor populations, whether it be at the bioregional or forest scale.

The effect of fires on goshawk populations has recently become an important question because of changes in burn regimes within goshawk habitats in North America. Until recently, there has been little research on how fire affects goshawks (Stone 2013). The 2013 and 2014 monitoring efforts provide evidence that goshawks occupy ponderosa pine forests within the burn perimeter at the same level as unburned ponderosa pine forests two and three years after a burn (Table 8). As more data are collected, we may also have the opportunity to determine if there are statistically significant differences on how goshawks occupy the burned versus unburned areas of the forest. Also, as seen in Figure 7, goshawks occupied PSUs in both 2013 and 2014 that suffered significant basal area loss due to the 2011 fire. Unfortunately, the current monitoring results cannot address if goshawk occupancy in the burned area is significantly different from before the burn because there was no forest-wide monitoring effort until after the burn took place. Because these results seem counterintuitive, the data collected for monitoring purposes might be used to investigate how, or if, burn intensity, regeneration or other fire characteristics affect goshawk occupancy. Long-term monitoring efforts can be used to determine how fires affect occupancy because, theoretically, you will eventually collect occupancy data from an area before and after a fire.

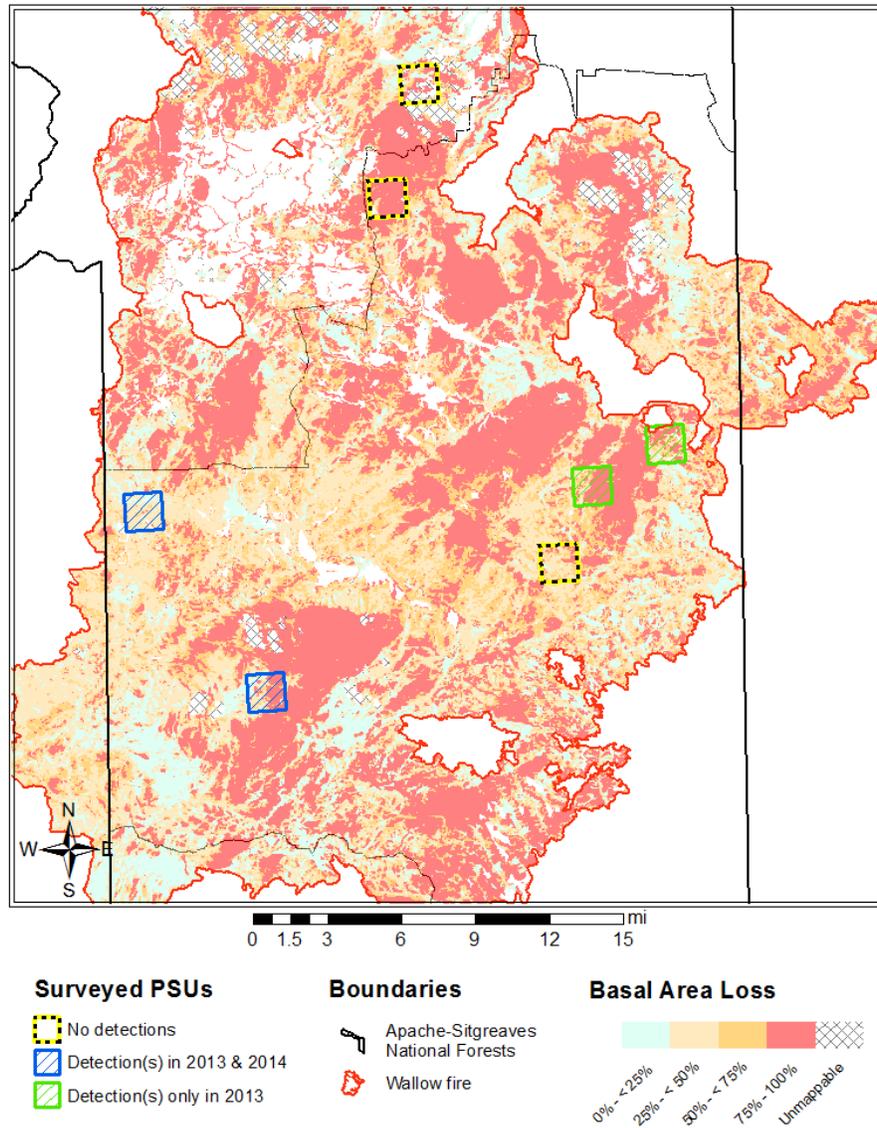


Figure 7. Occupied Northern Goshawk (*Accipiter gentilis*) Primary Sampling Units (PSU) surveyed in 2013 and 2014 and Wallow Fire burn intensity (based on basal area loss).

Consistent monitoring was accomplished between the 2013 and 2014 seasons and trend analysis was done to provide insight on year-to-year changes in goshawk populations in the Apache-Sitgreaves National Forests. Although the trend estimate, with only two years of data, had a high confidence interval, we should be able to provide better estimates each additional year goshawks are consistently monitored in the Apache-Sitgreaves National Forests, as is expected in 2015. Long-term monitoring can also possibly tease out environmental factors, such as disturbance (natural or man-made) and precipitation or prey abundance, that influence annual goshawk occupancy (Woodbridge and Hargis 2006). Some research suggests that cold, wet springs cause decreased nesting productivity for goshawks in more northern latitudes (Younk and Bechard 1994, Patla 2005). At first glance, a cold, wet spring does not appear to be the cause for decreased occupancy between the 2013 and 2014 field season. Although determining what covariates affect goshawk productivity, other than the burned and not-burned

stratification, is not currently part of the analysis of this monitoring effort, it would be interesting to explore these other covariates, including the possibility that warm and wet winters may positively affect goshawk productivity and how that relates to prey abundance in the area. With this knowledge, we could discuss recommendations with land managers to modify management practice to help maintain or increase Northern Goshawk populations within the area of study if desired.

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APPENDIX A

Northern Goshawk (*Accipiter gentilis*) survey results for each Primary Sampling Unit (PSU) visited during the Nestling (1 June – 6 July) and Fledgling seasons (7 July – 20 August), 2014 in the Apache-Sitgreaves National Forests, Ariz. Strata: MA = marginal habitat (pinyon-juniper woodland and subalpine forests); PF = primary habitat (ponderosa pine and mixed conifer forests) within the Wallow Fire burn perimeter; PN = primary habitat outside of the Wallow Fire burn perimeter. Detection Results: 1 = Surveyed with Detection; 0 = Surveyed without Detection.

PSU	Stratum	Rank	Nestling Season		Fledgling Season	
			Completion Date	Results	Completion Date	Results
AS-NOGO-MA1	MA	1	6/2/2014	0	8/20/2014	0
AS-NOGO-MA3	MA	3	6/17/2014	0	7/23/2014	0
AS-NOGO-MA4	MA	4	7/6/2014	0	7/24/2014	0
AS-NOGO-PF1	PF	1	6/8/2014	0	8/13/2014	0
AS-NOGO-PF2	PF	2	6/10/2014	1	8/18/2014	0
AS-NOGO-PF3	PF	3	6/16/2014	0	8/11/2014	1
AS-NOGO-PF4	PF	4	6/16/2014	0	8/6/2014	0
AS-NOGO-PF5	PF	5	6/17/2014	0	8/10/2014	0
AS-NOGO-PF7	PF	7	6/22/2014	0	8/4/2014	0
AS-NOGO-PF8	PF	8	6/23/2014	0	8/4/2014	0
AS-NOGO-PN1	PN	1	6/9/2014	0	7/9/2014	0
AS-NOGO-PN2	PN	2	6/25/2014	0	7/21/2014	0
AS-NOGO-PN3	PN	3	6/26/2014	0	7/28/2014	1
AS-NOGO-PN5	PN	5	6/25/2014	1	7/8/2014	0
AS-NOGO-PN6	PN	6	6/30/2014	0	7/14/2014	0
AS-NOGO-PN7	PN	7	7/2/2014	0	7/20/2014	0
AS-NOGO-PN8	PN	8	6/24/2014	1	8/19/2014	0
AS-NOGO-PN9	PN	9	6/12/2014	0	7/29/2014	0
AS-NOGO-PN10	PN	10	6/23/2014	0	7/7/2014	0
AS-NOGO-PN11	PN	11	7/1/2014	1	7/15/2014	0
AS-NOGO-PN12	PN	12	6/29/2014	0	8/3/2014	0

