Northern Goshawk Monitoring in the Apache-Sitgreaves National Forests: 2016 Field Season Report

September 2017

Bird Conservancy of the Rockies
14500 Lark Bunting Lane
Brighton, CO 80603
303-659-4348
www.birdconservancy.org

Tech. Report # USFS : NOGO-Apache-Sitgreaves
12-CS-11030109-031

Bird Conservancy of the Rockies

Connecting people, birds and land

Mission: Conserving birds and their habitats through science, education and land stewardship

Vision: Native bird populations are sustained in healthy ecosystems

Bird Conservancy of the Rockies conserves birds and their habitats through an integrated approach of science, education, and land stewardship. Our work radiates from the Rockies to the Great Plains, Mexico and beyond. Our mission is advanced through sound science, achieved through empowering people, realized through stewardship, and sustained through partnerships. Together, we are improving native bird populations, the land, and the lives of people.

Core Values:

1. **Science** provides the foundation for effective bird conservation.
2. **Education** is critical to the success of bird conservation.
3. **Stewardship** of birds and their habitats is a shared responsibility.

Goals:

1. Guide conservation action where it is needed most by conducting scientifically rigorous monitoring and research on birds and their habitats within the context of their full annual cycle.
2. Inspire conservation action in people by developing relationships through community outreach and science-based, experiential education programs.
3. Contribute to bird population viability and help sustain working lands by partnering with landowners and managers to enhance wildlife habitat.
4. Promote conservation and inform land management decisions by disseminating scientific knowledge and developing tools and recommendations.

Suggested Citation:
Berven, J.M. and D.C. Pavlacky. 2017. Northern Goshawk Monitoring in the Apache-Sitgreaves National Forests: 2016 Field Season Report. Tech. Rep. USFS : NOGO-Apache-Sitgreaves. Bird Conservancy of the Rockies, Brighton, CO, USA.
Cover Photo: Picture by Secca Roettenbacher.

Contact Information:
Jenny Berven
Jenny.Berven@birdconservancy.org
Bird Conservancy
14500 Lark Bunting Lane
Brighton, CO 80603
303-659-4348

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 its range falls within U.S. Forest Service's (USFS) administrative boundaries in the lower 48 states. However, little is known about the bird's population status across large spatial extents. The Northern Goshawk is classified as a sensitive species by the USFS and was a proposed 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 Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory) to assist in the development and implementation of Northern Goshawk monitoring using the technical guide as a reference. In 2013, we developed a grid of 1,481, 600-ha Primary Sampling Units (PSU) on the Apache-Sitgreaves National Forests in Arizona. We assigned each PSU into one of three strata based on information from the Apache-Sitgreaves cover-type and the Wallow Fire burn intensity data layers: pinyon-juniper woodland and subalpine forests, ponderosa pine forest, and ponderosa pine forest within the Wallow Fire burn perimeter. Within each stratum, we selected PSUs with a spatially balanced design using the Generalized Random Tessellation Stratified (GRTS) function (Spsurvey package) in R. We overlaid 120 call stations on ten transect lines (each containing 12 stations spaced 200 m apart) on PSUs.

Field technicians conducted broadcast acoustical surveys in selected PSUs during two time periods (nestling and fledgling) each summer from 2013 - 2016. We resampled nearly 100 percent of the original 21 PSUs; all 21 PSUs surveyed in 2013 were surveyed again in 2014 and 2015. One PSU was attempted in 2016 but was not resurveyed because of access issues. In exchange, technicians surveyed one backup PSU for the first time in 2016. We surveyed all PSUs twice in 2016, once between 30 May and 27 June and again between 3 July and 4 August 2016.

We estimated Northern Goshawk occupancy within the Apache-Sitgreaves National Forest using the MacKenzie et al. (2002) occupancy model. We used program MARK for parameter estimation, and the R package RMark for model construction. We estimated the occupancy rate separately for each stratum and year group using the sine link. We evaluated three models for the detection of the Northern Goshawk using the logit link, including a model that held the detection probability constant [$p(.)$], and models that allowed detection to vary by season (nesting and fledging periods) [$p(t)$] and year [p(year)].

In 2016, technicians detected goshawks in two PSUs during the nestling period and six PSUs during the fledgling period. The forest-wide detection probability was 0.377 and occupancy was 0.448 in 2016. Our analyses indicate goshawk occupancy in the Apache-Sitgreaves National Forests was highest in 2015 and lowest in 2014. In addition, there was no significant difference in occupancy between burned (0.645, CI: 0.295 – 0.924) and unburned (0.710, CI: 0.364 – 0.955) ponderosa pine forests.

We documented annual variation in goshawk occupancy throughout the four year monitoring effort. Goshawk occupancy experienced a 35% decline between 2013 and 2014, a 64% increase between 2014 and 2015, and a 67% decline between 2015 and 2016. This annual variation, and the confidence intervals for most years suggest the trends are not appreciably different from year to year and a measureable trend over the course of a four year monitoring effort is unlikely to provide significant evidence for changes in occupancy.

Bird Conservancy recommends continuing goshawk monitoring - if not annually, at least on a two- to four-year schedule - in the Apache-Sitgreaves to: further improve occupancy estimates, determine statistically significant trends, create a good foundation for additional analysis (e.g. habitat relationships) and supplement other USFS projects in the Region.

Acknowledgements

Elizabeth Humphrey of the United States Forest Service (USFS) was essential in development and funding of this monitoring effort and Shannon Houlette of the USFS was instrumental in continuing the monitoring. Staff within Bird Conservancy of the Rockies 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, Christina Pisani, Cassidy Ruge, Taylor Peacock, and Grant Stuefen 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 review by Nancy Drilling.

Table of Contents

Table of Figures

Table of Tables

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 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 size estimates are undetermined across vast areas because of difficulties associated with the low density of goshawks (≤12 nesting pairs/100-km^2) 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. These include 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 unknown if populations were increasing or stable. This interest in Northern Goshawk population assessment culminated with the creation of the USFS's "Northern Goshawk Inventory and Monitoring Technical Guide" (Woodbridge and Hargis) in 2006 which establishes a protocol to survey national forests within all USFS administrative regions within the Northern Goshawk's geographic range.

The Apache-Sitgreaves National Forests contracted Bird Conservancy of the Rockies (formally, Rocky Mountain Bird Observatory) 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 Bird Conservancy 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 within 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 individual forests within the region have conducted localized 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 because differences in monitoring protocols and methods exist.

In 2009, the first large-scale surveys were conducted within the Southwest Bioregion. Bird Conservancy 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 when less dominant goshawks are pushed to the woodlands only after all ponderosa pine or mixed coniferous territories have been filled (Reynolds et al., 1992; Drennan and Beier, 2003; Reynolds et al., 2008). In the 2009 study, Bird Conservancy estimated an occupancy rate 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 should not be excluded from the monitoring effort if a forest-wide occupancy estimate is desired.

Monitoring Northern Goshawk populations is a challenge because of 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 annual changes in Northern Goshawk populations without the need for extensive abundance surveys (MacKenzie and Nichols, 2004; Woodbridge and Hargis, 2006). Occupancy analysis determines what fraction of a landscape is occupied by a species, whereas abundance estimates determine 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 which started on 29 May, 2011 and burned more than 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: 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 after a large and destructive fire? Bird Conservancy's current monitoring effort within the Apache-Sitgreaves National Forest can simultaneously address both questions by stratifying areas of interest based on habitat and burn status. 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).

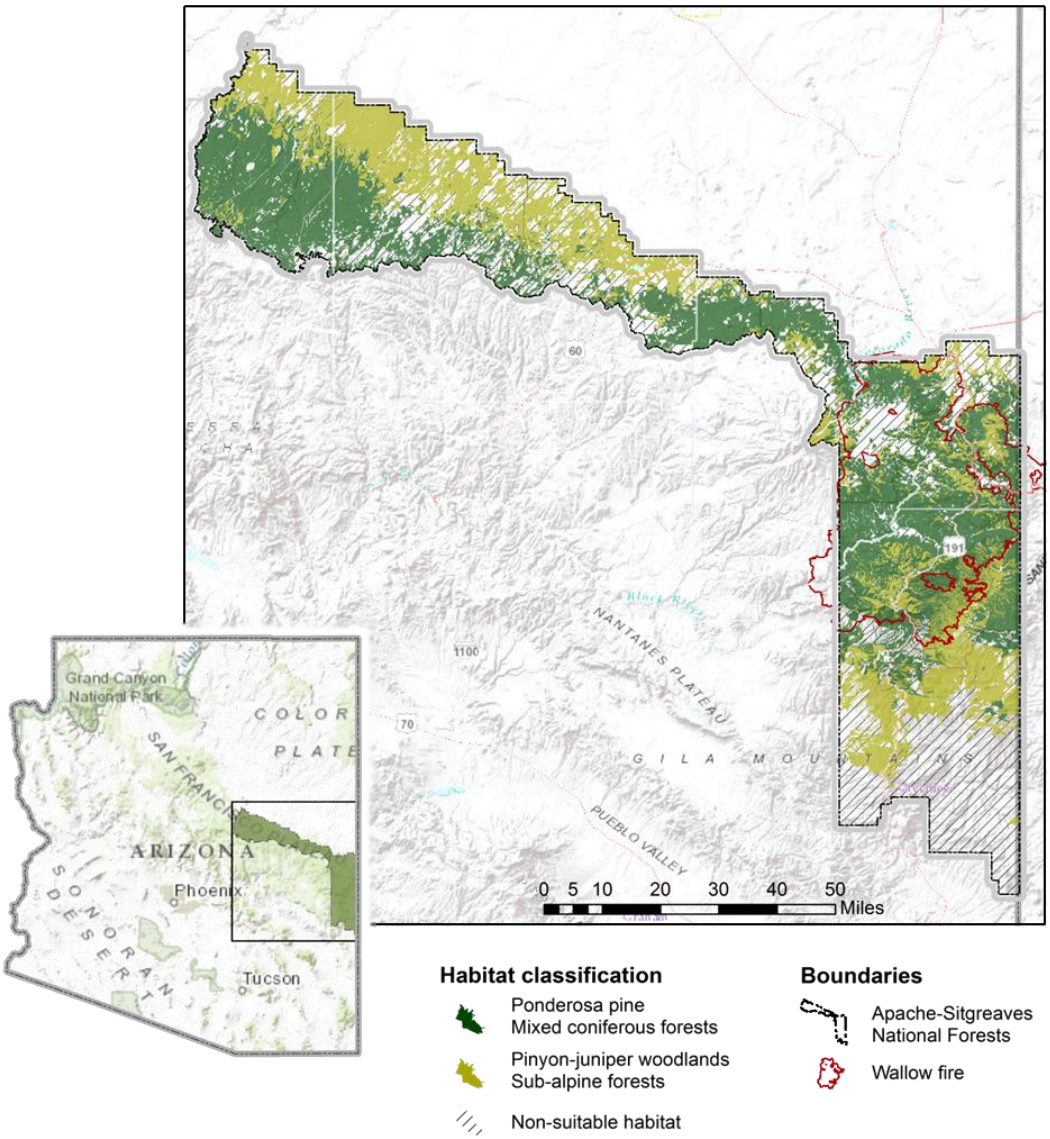

Figure 1. Classification of suitable habitat for the Northern Goshawk (*Accipiter gentilis*) in the Apache-Sitgreaves National Forests, Arizona, 2013 - 2016.

Sampling Design

Sample Selection

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), we created a region-wide grid by overlaying

600 ha PSUs onto a USFS administrative border layer. We then defined the sampling frame as the set of PSUs containing a minimum of 20% potential Northern Goshawk habitat based on Apache-Sitgreaves data layers. We classified each grid cell within the administrative boundary into marginal habitat (pinyon-juniper woodland and subalpine forests; *n* = 383), 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. Number of Primary Sampling Units (PSUs) allocated to each stratum in Apache Sitgreaves National Forest.

	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

We implemented a spatially balanced study design to select PSUs for survey, using the generalized random-tessellation stratification (GRTS) function (Spsurvey package) in R (Stevens, 2004). We selected and surveyed the same PSUs for the 2016 field season as we did for the 2013 – 2015 field seasons. A grid of call station points was added to each selected PSU using ArcGIS. For PSUs located completely within the USFS administrative boundary, 120 call stations on ten transect lines (each containing 12 stations spaced 200 m apart) were overlaid on the PSU (Figure 2). Transect lines were 250 m apart and located at least 150 m from the PSU border. Call stations on adjacent transect lines were offset by 100 m. For PSUs located on the USFS administrative boundary, all call stations outside of Forest Service land were removed from the survey effort. We identified call stations in unsuitable locations (slope >36°, >150 m away from forest cover or on private land) 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, the Apache-Sitgreaves cover-type layer (United States Forest Service, 2012) to identify call stations >150 m from tree cover, and the USFS Surface Ownership layer (United States Forest Service. Southwest Region., 2012b) to identify and label call stations located on private land. All call stations within the administrative boundary were labeled according to suitability criteria on maps (Figure 2).

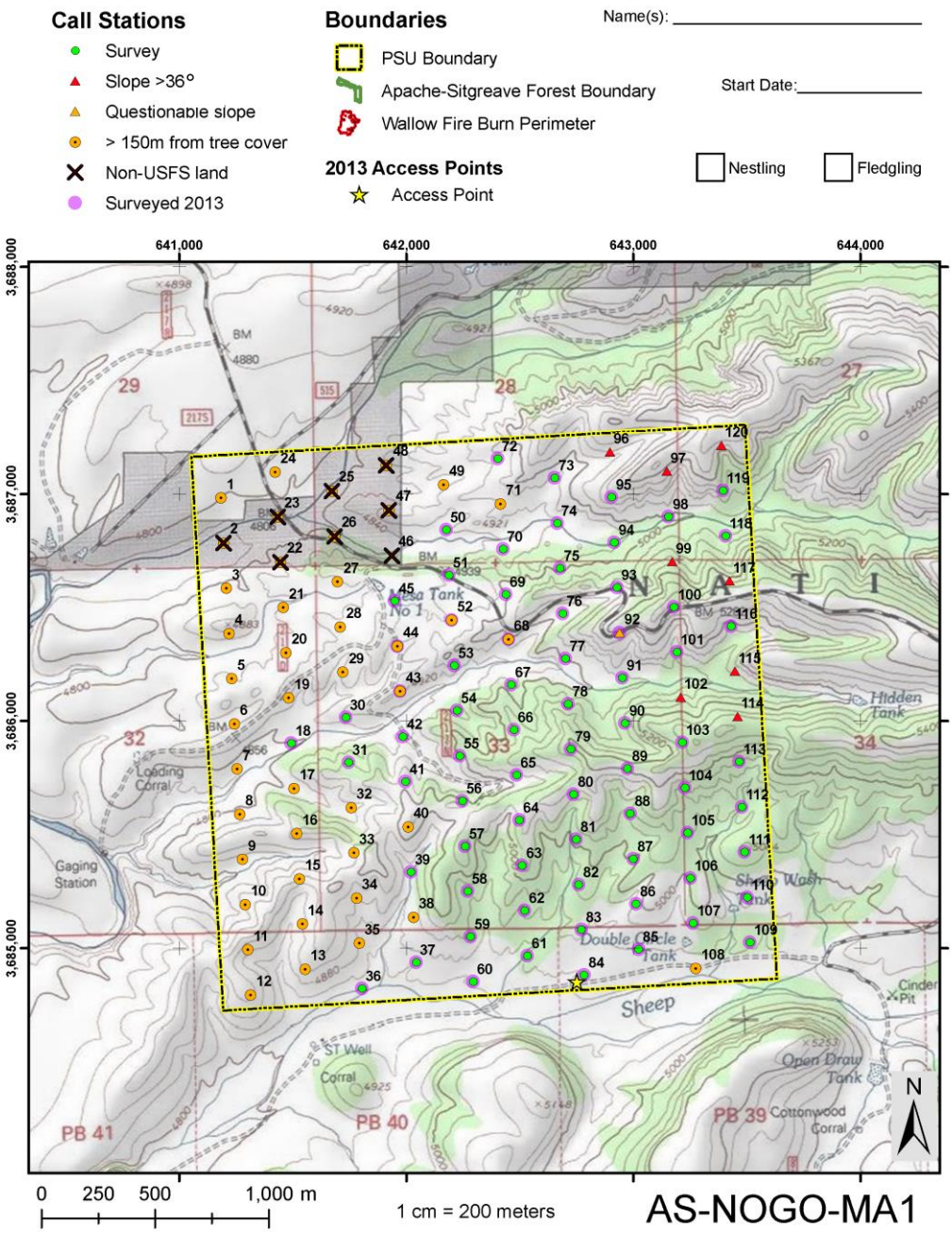

Figure 2. Example of a Primary Sampling Unit (PSU) map used by technicians throughout the field season to survey for Northern Goshawks (*Accipiter gentilis*) in the Apache-Sitgreaves National Forests, Arizona, 2013 – 2016.

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

Sampling Methods

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. We implemented a schedule of repeated surveys of PSUs in 2013 corresponding to a double sampling design with two survey occasions (MacKenzie et al. 2006). Repeat surveys were conducted for all PSUs with no detections in the first occasion and repeat surveys were conducted for a random sample of PSUs with detections in the first occasion (67%). In 2014, 2015, and 2016, all PSUs received a second visit.

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, we utilized observations 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, before nestlings began to fledge. The fledgling surveys began once nestlings moved away from the nest (approximately when young are 34 days old) and ended approximately six weeks after fledging when juvenile goshawks typically disperse from the area.

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. Technicians broadcast one of three Northern Goshawk calls depending on whether it was the nestling or fledgling survey ((Woodbridge and Hargis, 2006). During the nestling survey, an adult alarm call was broadcast while 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 three times (and the circle completed), technicians waited, watched and listened for two minutes, then repeated the cycle. After two full rounds of playing the call, technicians recorded any significant findings and time spent at each call station on a standardized field form. They 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.

Data Analysis

Occupancy estimation

We estimated 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 8.0, www.phidot.org, accessed 10 February 2016), and the R package RMark for model construction (RMARK Version 2.1.13, accessed 10 February 2015; R Version 3.2.2, www.R-project.org, accessed 10 February 2016). We estimated occupancy separately for each stratum (marginal, primary – not burned, primary – burned) and year group using the sine link. We evaluated 3 models for the detection of the Northern Goshawk using the logit link, including a model that held the detection probability constant [$p(.)$], and models that allowed detection to vary by season (nesting and fledging periods) [$p(t)$] and year [p(year)]. We did not model detection probability as a function of strata and effort because low detection probabilities at certain covariate values resulted in biased estimates of occupancy. According to MacKenzie et al. (2002), an occupancy model with 2 repeat surveys may not perform well unless $\hat{p} > 0.3$ and $\widehat{\psi} > 0.7$. Four repeat surveys are the optimal number of repeats for estimating the probabilities of detection ($\hat{p} \approx 0.4$) and site occupancy ($\widehat{\psi} \approx 0.5$) observed in this study (Mackenzie and Royle, 2005).

We estimated Northern Goshawk detection and occupancy 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 in 2016 was estimated by

$$\widehat{\psi}_{2016} = \sum_{i=1}^{3} w_i \widehat{\psi}_i,$$

where the number of strata was 3, the weight w_i was the proportion of PSUs in stratum i, and $\widehat{\psi}_i$ 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) within the R environment. 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 90% confidence intervals (CI) for the occupancy and detection estimates by back-transforming the logit or sine 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 between successive years using the equation

$$\hat{\lambda}_{\psi_{ij}} = \frac{\widehat{\psi}_j}{\widehat{\psi}_i},$$

where i represented the estimate for the first year and j represented the estimate for the second year (Yoccoz et al., 2001). 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 between successive years. We approximated sampling variances and standard errors for the trend using the delta method (Powell, 2007).

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 90% CIs for all models in the candidate set (Burnham and Anderson, 2002).

Results

In 2016, we surveyed 21 PSUs one time during the nestling survey window and one time during the fledgling survey window (Table 2, Figure 3, Appendix A). Because hatching was estimated to have occurred late-May to early-June 2016, nestling surveys began on 30 May 2016. Fledgling surveys began 3 July and continued until all planned PSUs were resurveyed (4 August 2016).

In 2013, we surveyed 50% of PSUs with a nestling detection but due to the low detection during the 2014 nestling survey window, we re-surveyed all PSUs during the fledgling survey window found re-surveying all PSUs did not add a significant cost to the project. In 2016, technicians made a total of eight goshawk detections throughout the field season (Table 3, Figure 4); two during the nestling surveys and six during the fledgling surveys.

Table 2. Primary Sampling Units (PSUs) sampled in the Apache-Sitgreaves National Forests during the 2016 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

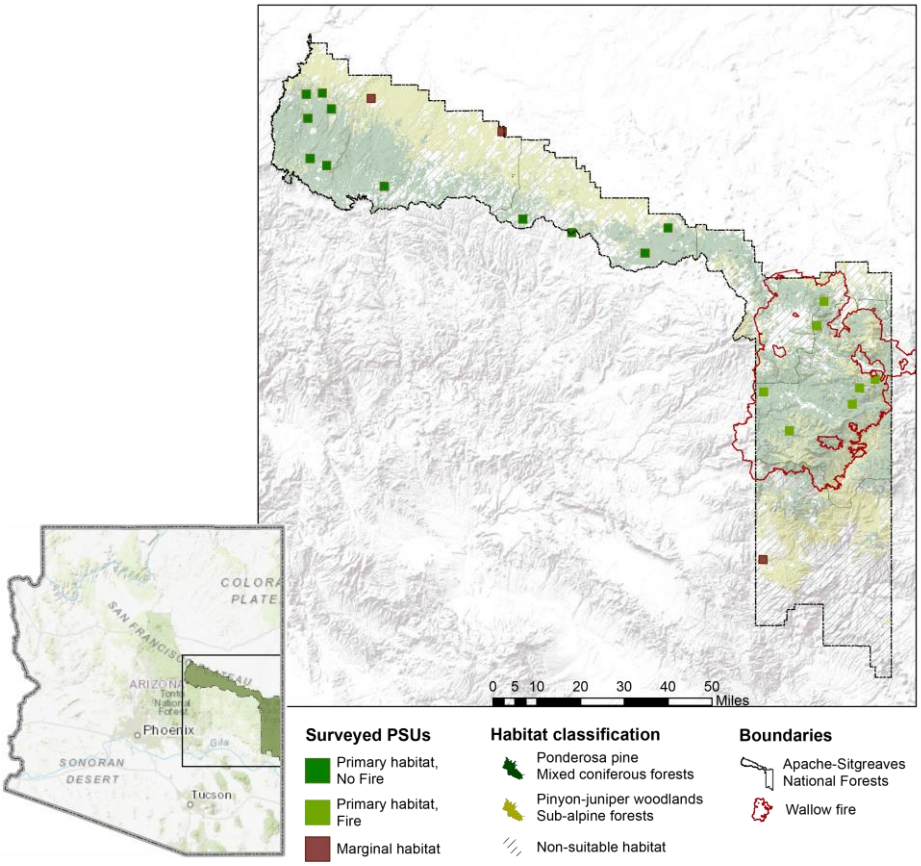

Figure 3. Primary Sampling Units (PSUs) surveyed for Northern Goshawks (Accipiter gentilis) in the Apache-Sitgreaves National Forests, May-August, 2016.

Table 3. Total Northern Goshawk (Accipiter gentilis) detections in the Apache-Sitgreaves National Forests, May-August, 2016.

Strata	Nestling Season Detections	Fledgling Season Detections	Total
Primary - unburned	0	5	5
Primary - burned	2	1	3
Marginal habitat	0	0	0
Total	2	6	8

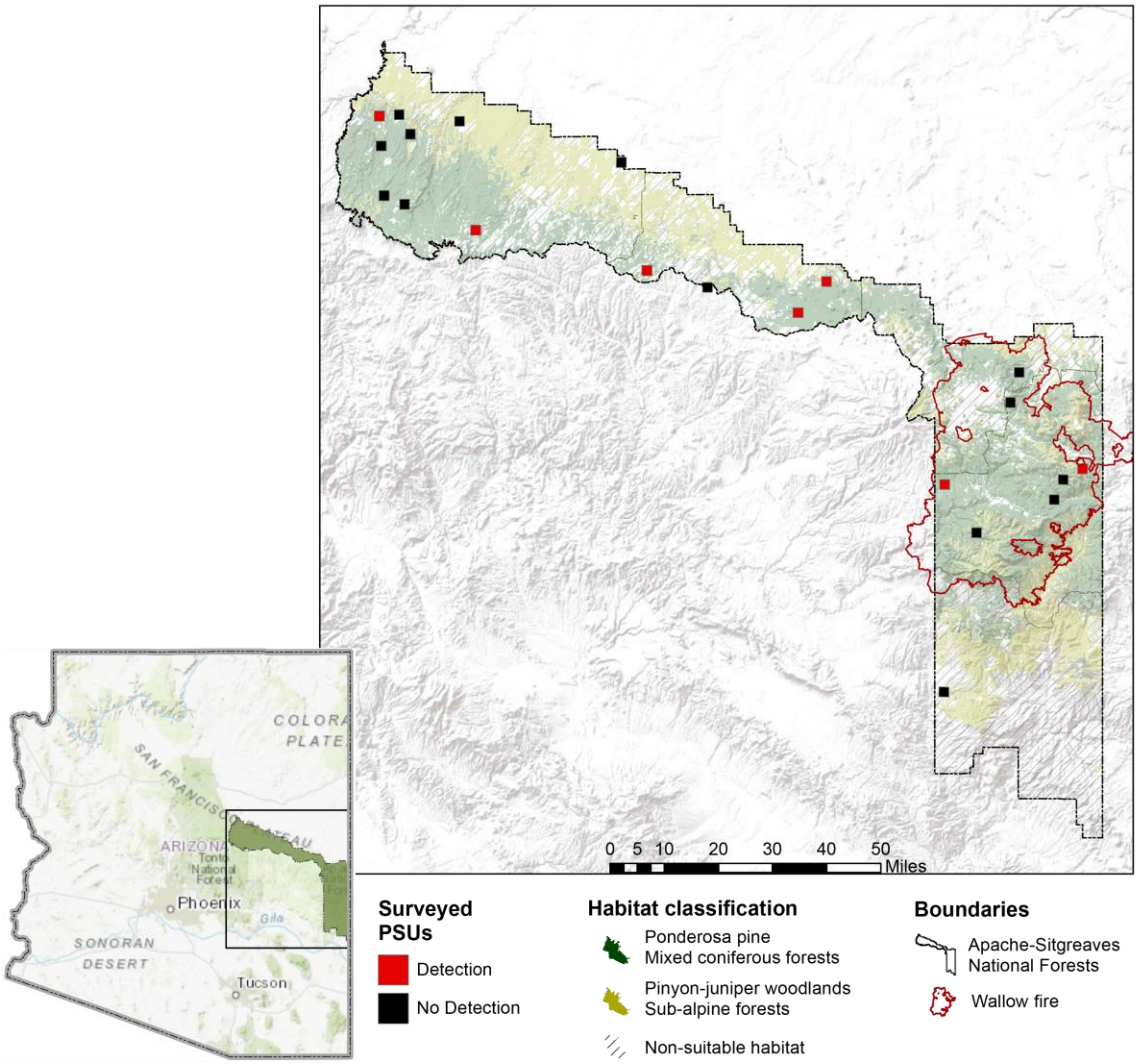

Figure 4. Northern Goshawk (*Accipiter gentilis*) detections, May-August, 2016 in surveyed Primary Sampling Units (PSUs) in the Apache-Sitgreaves National Forests.

Over the course of the four-year monitoring effort, there were five PSUs where technicians never detected a goshawk (Figure 5). Technicians did not detect a goshawk in two PSUs in the MA stratum; those PSUs were each surveyed eight times. Similarly, technicians did not detect a goshawk in two PSUs within the burn perimeter; those PSUs were each surveyed eight times.

The fifth PSU where technicians had no detection was in the PN stratum, however, it was only surveyed in the final year as it was a backup to AS-NOGO-PN8, which was inaccessible in 2016.

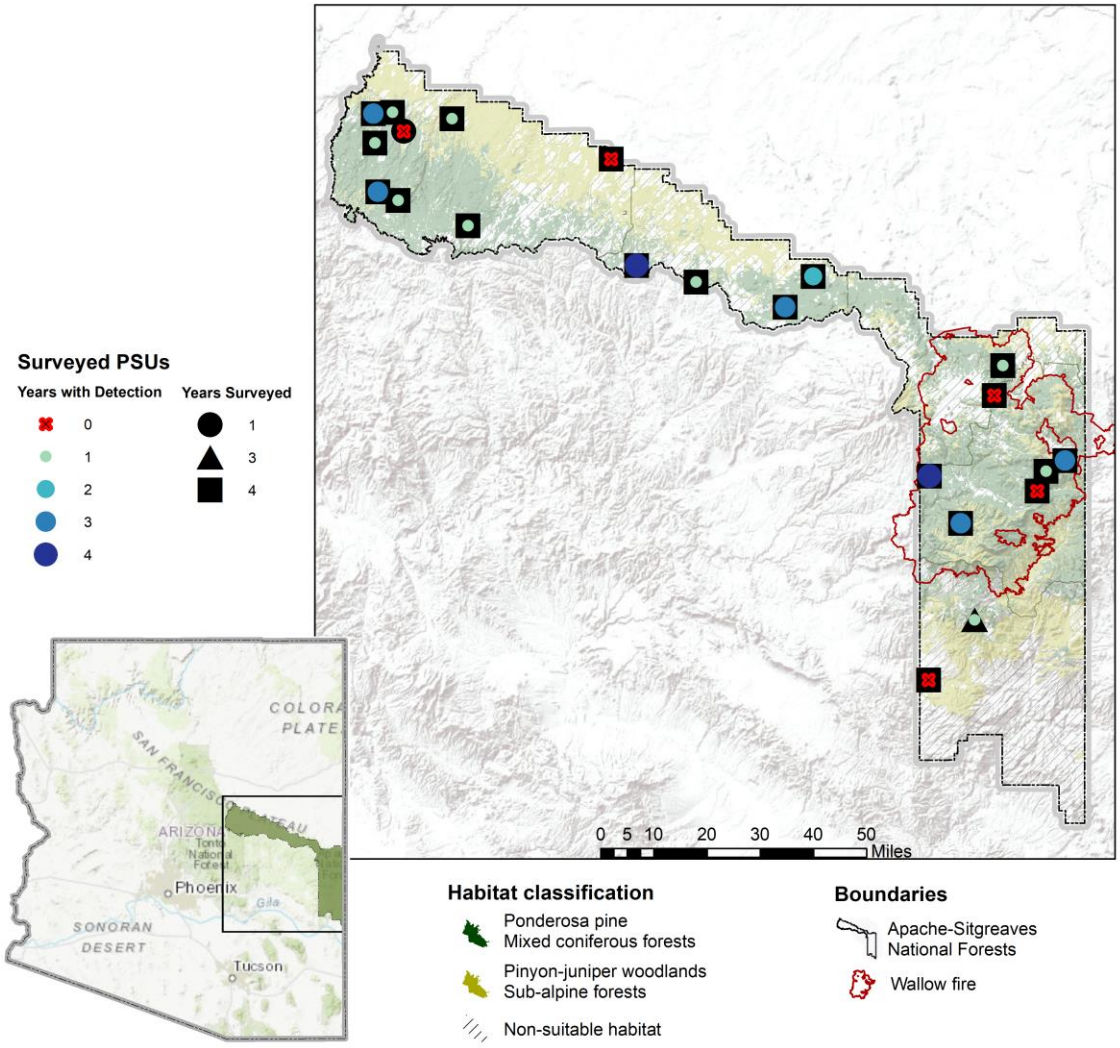

Figure 5. Number of years in which a Northern Goshawk (*Accipiter gentilis*) was detected for each Primary Sampling Unit (PSU) and the number of years PSUs were surveyed in the Apache-Sitgreaves National Forests, Arizona, 2013 – 2016.

Using all four years of data, the best model for the occupancy of Northern Goshawks contained a constant rate of detection (Table 4, Table 5). The second best model containing the effect of nesting and fledging seasons on detection was not considered a competing model because adding the effect of season did not appreciatively decrease the $-2\log_e(L)$ of the model (Table 1, Arnold, 2010). The top model with a constant effect of detection was 14 times more plausible than the third best model with the effect of Year on detection (Table 4).

Table 4. Model selection for estimating the detection and occupancy rates of the Northern Goshawk in the Apache-Sitgreaves National Forest, 2013 - 2016, Arizona, USA. 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), difference between model and minimum AIC_c values (ΔAIC_c) and AIC_c weight (w_i).

Model	***K***	**-2log(*L*)**	**AIC_c**	**ΔAIC_c**	**w_i**
***p*(.) ψ(Stratum*Year)**	13	162.14	193.34	0.00	0.707
***p*(*t*) ψ(Stratum*Year)**	14	161.39	195.48	2.14	0.242
***p*(Year) ψ(Stratum*Year)**	16	158.48	198.60	5.26	0.051

Table 5. Combined model averaged estimates of the probability of detection, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 90% confidence limits, respectively for the Northern Goshawk in the Apache-Sitgreaves National Forest, 2013 - 2016, Arizona, USA.

Parameter	**Estimate**	**SE**	**CV**	**LCL**	**UCL**
Nesting	0.366	0.114	0.311	0.204	0.565
Fledging	0.387	0.122	0.314	0.213	0.595
2013	0.388	0.125	0.321	0.210	0.601
2014	0.366	0.117	0.319	0.201	0.570
2015	0.383	0.117	0.305	0.215	0.584
2016	0.371	0.112	0.301	0.211	0.565
Apache-Sitgreaves National Forest	0.377	0.115	0.306	0.212	0.576

As expected, Northern Goshawk occupancy rates were lower in the pinyon-juniper stratum than in the ponderosa pine and burned ponderosa pine strata (Figure 6, Table 6). However there were no appreciable occupancy rate differences between the ponderosa pine and burned ponderosa pine strata (Table 6, Table 7). There was some evidence for a 35% decline ($\hat{\lambda}_{\psi_{ij}}$= 0.65, SE = 0.85) in the occupancy rate of the Northern Goshawk in the Apache-Sitgreaves National Forest from 2013 to 2014 (Figure 7, Table 6). However, the CI for the trend in occupancy covered 1 (CI = 0.07, 5.60), suggesting the trend was not appreciably different from 1. There was considerable evidence for an 64% increase ($\hat{\lambda}_{\psi_{ij}}$= 1.64, SE = 0.35) in occupancy from 2014 to 2015 (Figure 7, Table 6). The CI did not cover 1 (CI = 1.15, 2.33), indicating a large and precise effect size for the difference between years. There was some evidence for a 67% decline ($\hat{\lambda}_{\psi_{ij}}$= 0.67, SE = 0.79) in the occupancy rate of the Northern Goshawk in the Apache-Sitgreaves National Forest from 2015 to 2016 (Figure 7, Table 6), but the CI for the trend in occupancy covered 1 (CI = 0.09, 4.64), suggesting the trend was not appreciably different from 1.

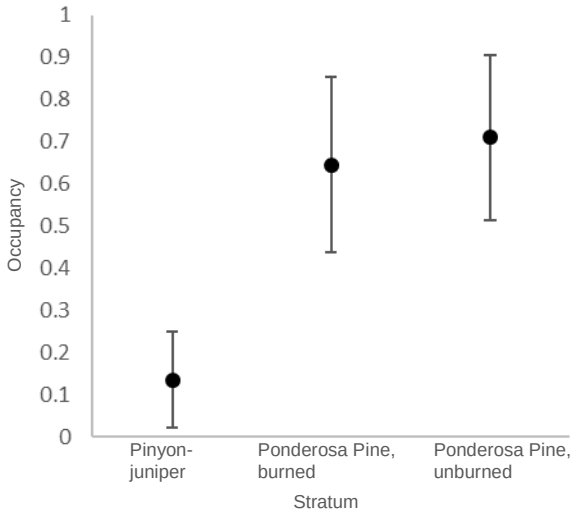

Figure 6. Occupancy rates for the Northern Goshawk (*Accipiter gentilis*) in three strata in the Apache-Sitgreaves National Forest, Arizona, May-August, 2016, with 90% confidence intervals.

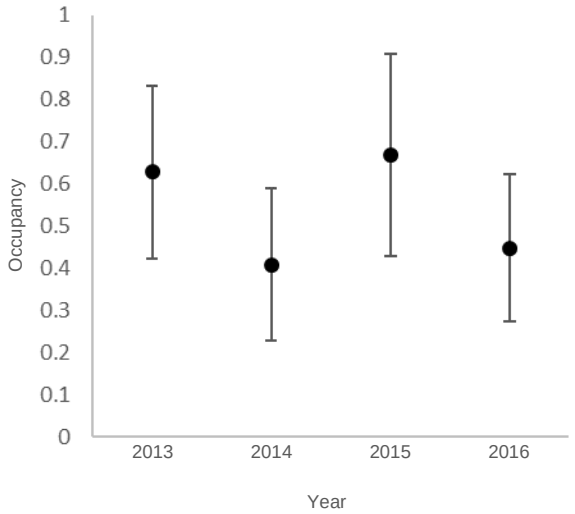

Figure 7. Yearly occupancy rates for the Northern Goshawk (*Accipiter gentilis*) in the Apache-Sitgreaves National Forest, 2013 - 2016, Arizona, USA, with 90% confidence intervals.

Table 6. Combined model averaged estimates of the probability of occupancy, and unconditional standard errors (SE), coefficients of variation (CV), and lower (LCL) and upper (UCL) 90% confidence limits, respectively for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2016.

Parameter	Estimate	SE	CV	LCL	UCL
Pinyon-juniper	0.135	0.114	0.847	0.010	0.368
Ponderosa pine-burned	0.645	0.208	0.323	0.295	0.924
Ponderosa pine	0.710	0.195	0.275	0.364	0.955
Apache-Sitgreaves National Forest - 2013	0.628	0.206	0.328	0.286	0.910
Apache-Sitgreaves National Forest - 2014	0.408	0.181	0.444	0.144	0.704
Apache-Sitgreaves National Forest - 2015	0.669	0.239	0.357	0.264	0.963
Apache-Sitgreaves National Forest - 2016	0.448	0.174	0.389	0.185	0.728
Apache-Sitgreaves National Forest	0.538	0.142	0.264	0.308	0.760

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) 90% confidence limits, respectively for the Northern Goshawk in the Apache-Sitgreaves National Forest, Arizona, USA, 2013 - 2016.

Year	Stratum	Estimate	SE	CV	LCL	UCL
2013	Pinyon-juniper	0.000	0.000	-	-	-
2013	Ponderosa pine-burned	0.921	0.368	0.399	0.002	1.000
2013	Ponderosa pine	0.733	0.294	0.402	0.134	0.989
2014	Pinyon-juniper	0.000	0.000	-	-	-
2014	Ponderosa pine-burned	0.489	0.339	0.693	0.012	0.983
2014	Ponderosa pine	0.615	0.278	0.453	0.111	0.989
2015	Pinyon-juniper	0.540	0.457	0.847	0.005	0.977
2015	Ponderosa pine-burned	0.694	0.341	0.491	0.066	0.981
2015	Ponderosa pine	0.736	0.294	0.400	0.135	0.988
2016	Pinyon-juniper	0.000	0.000	-	-	-
2016	Ponderosa pine-burned	0.476	0.307	0.646	0.024	0.958
2016	Ponderosa pine	0.756	0.293	0.387	0.141	0.978

Discussion

Nationally, the status of the Northern Goshawk remains of interest because not enough is known about their population and because 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 Southwest Bioregional monitoring effort was the first step in accomplishing large-scale monitoring goals by creating the sampling grid, selecting PSUs based on habitat types and access, and implementing the field research across the region. However, there remained a need to develop and implement local, smaller-scale Northern Goshawk monitoring to provide reliable data for the evaluation of the species’ status within smaller management units. This monitoring effort attempts to do this.

Short-term comparisons of annual survey results usually mean little because annual goshawk breeding success varies significantly among years (Reich et al., 2004; Patla, 2005; MacKenzie et al., 2006). This was evident in the rise and fall in forest-wide occupancy throughout this monitoring effort. If forest-wide trend is desired by the Forests, Bird Conservancy recommends long-term monitoring efforts as directed by the Technical Guide. Current trend analysis provides some insight in annual variance in goshawk populations in the Apache-Sitgreaves National Forests but does not yet provide a useful population trend. The Northern Goshawk Technical Guide suggests trend not be analyzed until after the fifth year at the Bioregional scale. Our results, however, do provide some indication of a slight positive trend in forest-wide occupancy for the Apache-Sitgreaves National Forests during this monitoring effort. Long-term monitoring may also tease out environmental factors, such as disturbance (natural or man-made), precipitation or prey abundance, that influence annual forest-wide goshawk occupancy (Woodbridge and Hargis, 2006). Although determining factors that affect goshawk occupancy is not currently part of the analysis of this monitoring effort, it would be interesting to explore these factors, including the possibility that warm and wet winters may result in higher forest-wide

occupancy. With this knowledge, we could discuss management recommendations that help maintain or increase Northern Goshawk populations within the area of study.

To obtain a clearer picture of how goshawks are utilizing the burned versus unburned areas of the Apache-Sitgreaves, continued annual monitoring effort should increase precision in the occupancy estimates. Alternatively, we could conduct fewer years of monitoring but increase the sample size within each survey year. Bird Conservancy ran a power analysis for the Four Forest Restoration Initiative work in Arizona to determine the sample size needed to detect differences between pre- and post-treatment goshawk occupancy. The power analysis assumed a pre-treatment occupancy rate of 44% and determined a sample size of 80 PSUs (40 each in pre-treatment and post-treatment strata) was nearly large enough to detect a 50% increase in occupancy at the 90% confidence level. After four years of surveys for the Apache-Sitgreaves National Forests, we have surveyed the burned stratum 28 times and unburned stratum 44 times. Monitoring efforts thus far have found that occupancy estimates in the burned and unburned habitats are statistically the same. The effect of fires on goshawk populations is 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 - 2016 Apache-Sitgreaves monitoring efforts provide evidence that goshawks occupy ponderosa pine forests within the burn perimeter at the same level as unburned ponderosa pine forests two to five years after a burn (Figure 6). However, the current monitoring results cannot determine if goshawk occupancy in the burned area is significantly different from before the burn because there was no forest-wide monitoring until after the burn took place. The data collected from the current monitoring effort might be used to investigate how, or if, burn intensity, regeneration or other fire characteristics affect goshawk occupancy.

If further goshawk monitoring is requested, two major factors should be considered. First, project costs have increased, yet funding to Bird Conservancy has remained constant at $45,000 per year. The first year typically includes project start-up costs (e.g. supply purchases, project design and sample draw) that are not required the second year. These savings usually help mitigate subsequent annual cost increases due to factors such as inflation. However, by the third year, costs (e.g. inflation and supply replacements) begin to out-pace savings from the original project budget. If the Apache-Sitgreaves National Forests and Bird Conservancy continue monitoring efforts, a new budget will need to be discussed, as well as evaluation of sample sizes and distribution of PSUs between the different strata. For example, four years of monitoring show that goshawks rarely occupy the pinyon-juniper PSUs. Bird Conservancy could eliminate this stratum from the survey effort to concentrate on the burned and unburned Pondera Pine strata however, that is not recommended as it would change the meaning of the forest-wide occupancy estimate. Additionally, goshawks are presumed to follow ideal free distribution models where they occupy territories within primary habitats at fairly consistent rate and only occupy marginal habitat as competition within the primary habitat forces less dominant individuals into the marginal habitat. Changes in marginal habitat occupancy are the first indication of significant changes in forest-wide occupancy (Woodbridge and Hargis, 2006).

The second factor to consider is that the Four Forest Restoration Initiative (4FRI) is conducting goshawk monitoring in the Apache-Sitgreaves, Coconino, Kaibab and Tonto National Forests to 1) evaluate the effects of 4FRI treatments on Northern Goshawk occupancy and 2) determine the resulting effects of landscape heterogeneity on Northern Goshawk occupancy. The 4FRI sampling frame consists of rotating panels that are to be treated and monitored. The sampling frame includes Panel 1 (task orders 1-3), Panel 2 (task orders 4-6) and Panel 3 (task orders 7-9). The sampling strategy will be to survey the PSUs before and after the 4FRI treatments in a rotating panel design (Table 8).

Table 8. Before and after rotating panel design for three sets of task orders for the Four Forest Restoration Initiative.

Year	Panel 1	Panel 2	Panel 3
1 (2015)	X		
2	X	X	
3		X	X
4			X

Panel 1 was monitored in 2015, before treatment, and will be monitored again after treatment. We hope to conduct Panel 2's "before treatment" surveys in the same year as Panel 1's "after treatments" surveys, then replicate the process for Panel 3 in subsequent years. The 4FRI goshawk monitoring efforts are scheduled to occur every three to five years to allow time for restoration treatments to occur at task order sites and additional time to recover from the treatment. In 2015, we were able to supplement the low survey effort in the 4FRI with the Apache-Sitgreaves forest-wide effort and hope to do this again in the future.

Bird Conservancy recommends continuing goshawk monitoring in the Apache-Sitgreaves to: further improve occupancy estimates, determine statistically significant trends, create a good foundation for additional analysis (e.g. habitat relationships) and supplement other USFS projects in the Region. After four consecutive years of monitoring efforts that established annual variation in goshawk occupancy, annual monitoring is most likely no longer required. However, we recommend continuing monitoring that coordinates with the 4FRI project as well as at a frequency between every two to four years.

Literature Cited

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. In: B. N. Petrov and F. Csaki (eds.) Second International Symposium on Information Theory. p 267–281. Akademiai Kiado, Budapest, Hungary.

Anderson, D. E. et al. 2005. Technical review of the status of northern goshawks in the Western United States. Journal of Raptor Research 39: 192-209.

Arnold, T. W. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. Journal of Wildlife Management 74: 1175–1178.

Berven, J. M., Pavlacky, D.C. 2010. Northern Goshawk Monitoring in the Southwest United States: 2009 Field Season Report. Rocky Mountain Bird Observatory Accessed Date Accessed.| doi:DOI|

Burnham, K. P., and D. R. Anderson. 2001. Kullback-Leibler Information as a basis for strong inference in ecological studies. Wildlife Research 28: 111-119.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Drennan, J. E., and P. Beier. 2003. Forest Structure and Prey Abundance in Winter Habitat of Northern Goshawks. The Journal of Wildlife Management 67: 177-185.

Hurvich, C. M., and C. L. Tsai. 1989. Regression and time-series model selection in small samples. Biometrika 76: 297-307.

Kullback, S., and R. A. Leibler. 1951. On information and sufficiency. Annals of Mathematical Statistics 22: 79-86.

MacKenzie, D. I., and J. D. Nichols. 2004. Occupancy as a surrogate for abundance estimation. Animal biodiversity and conservation 27: 461-467

MacKenzie, D. I. et al. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83: 2248-2255.

MacKenzie, D. I. et al. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier, Burlington, VT.

Mackenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42: 1105-1114.

Patla, S. M. 2005. Monitoring Results of Northern Goshawk Nesting Areas in the Greater Yellowstone Ecosystem: Is Decline in Occupancy Related to Habitat Change? Journal of Raptor Research 39: 324-334.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. Condor 109: 949-954.

Reich, R. M., S. M. Joy, and R. T. Reynolds. 2004. Predicting the location of northern goshawk nests: modeling the spatial dependency between nest locations and forest structure. Ecological Modelling 176: 109-133.

Reynolds, R. T., R. T. Gpkham, and D. A. Boyce. 2008. Northern goshawk habitat: An intersection of science, management, and conservation. Journal of Wildlife Management 72: 1047-1055.

Reynolds, R. T. et al. 1992. Management recommendations for the northern goshawk in the Southwestern United States, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Reynolds, R. T., and S. M. Joy. 1998. Distribution, territory occupancy, dispersal, and demography of northern goshawks on the Kaibab Plateau, Arizona.

Squires, J. R., and R. T. Reynolds. 1997. Northern Goshawk (Accipiter gentilis). In: A. a. F. Gill (ed.) The Birds of North America No. No. 298. The Academy of Natural Sciences. Philadelphia, PA and The American Ornithologists' Union. Washington, DC, U.S.A.

Squires, J. R., and L. F. Ruggiero. 1996. Nest-Site Preference of Northern Goshawks in Southcentral Wyoming. The Journal of Wildlife Management 60: 170-177.
Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99: 262-278.
Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99: 262-278.
Stone, K. R. 2013. Accipiter gentilis. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). .
United States Fish and Wildlife Service. 1997. Endangered and threatened wildlife and plants: 90-day finding for a petition to list the northern goshawk in the contiguous United States west of the 100th meridian. In: Federal Register (ed.) No. 62. p 50892–50896.
United States Fish and Wildlife Service. 1998. Endangered and threatened wildlife and plants: notice of 12-month finding on a petition to list the northern goshawk in the contiguous United States west of the 100th meridian. In: Federal Register (ed.) No. 63. p 35183–35814.
United States Forest Service. 1991. Planning for management and recovery No. FSM 2672 Amend. 2600-91-4. Department of Agriculture, Forest Service, Washington, DC: U.S.
United States Forest Service. 1995. Threatened, endangered and sensitive plants and animals No. FSM 2670 Amend. 2600-95-7. U.S. Department of Agriculture, Forest Service, Washington, DC.
United States Forest Service. 2009. Area of sampled forest land by Forest type and Ownership group - Arizona & New Mexico National Forest Inventory and Analysis - Forest Inventory Data Online. p 1.
United States Forest Service. 2012. APSVegCoverType. USDA.
United States Forest Service. Southwest Region. 2011. RAVG_20110718_Wallow. USDA Forest Service.
United States Forest Service. Southwest Region. 2012a. APSVegCoverType. USDA Forest Service.
United States Forest Service. Southwest Region. 2012b. Surface Ownership. USFS Southwestern Regional Office.
Wadleigh, L. 2011. Wallow Fire 2011, Fire/Fuels Report, Apache-Sitgreaves National Forests. In: L. S. E. R. R. A. Team (ed.). USDA Forest Service, Southwest Region.
Woodbridge, B., and C. D. Hargis. 2006. Northern Goshawk Inventory and Monitoring Technical Guide, United States Dept. of Agriculture, Forest Service, Washington D.C.
Yoccoz, N. G., J. D. Nichols, and T. Boulinier. 2001. Monitoring of biological diversity in space and time. Trends in Ecology & Evolution 16: 446-453.

Appendix A

Northern Goshawk (*Accipiter gentilis*) survey results for each Primary Sampling Unit (PSU) visited during the Nestling (30 May – 27 June) and Fledgling seasons (3 July – 4 August), 2016 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.

			Nestling Season		Fledgling Season	
PSU	Stratum	Rank	Completion Date	Results	Completion Date	Results
AS-NOGO-MA1	MA	1	6/1/2016	0	7/18/2016	0
AS-NOGO-MA3	MA	3	5/31/2016	0	7/25/2016	0
AS-NOGO-MA4	MA	4	6/20/2016	0	7/20/2016	0
AS-NOGO-PF1	PF	1	6/5/2016	0	7/15/2016	0
AS-NOGO-PF2	PF	2	6/15/2016	0	7/16/2016	0
AS-NOGO-PF3	PF	3	6/6/2016	1	7/19/2016	1
AS-NOGO-PF4	PF	4	5/31/2016	1	7/12/2016	0
AS-NOGO-PF5	PF	5	6/14/2016	0	7/13/2016	0
AS-NOGO-PF7	PF	7	6/3/2016	0	7/29/2016	0
AS-NOGO-PF8	PF	8	6/7/2016	0	7/29/2016	0
AS-NOGO-PN1	PN	1	6/27/2016	0	7/22/2016	0
AS-NOGO-PN2	PN	2	6/18/2016	0	8/2/2016	0
AS-NOGO-PN3	PN	3	6/16/2016	0	8/4/2016	1
AS-NOGO-PN5	PN	5	6/8/2016	0	7/21/2016	1
AS-NOGO-PN6	PN	6	6/4/2016	0	7/4/2016	0
AS-NOGO-PN7	PN	7	6/14/2016	0	7/31/2016	0
AS-NOGO-PN8	PN	8	n/a	-1	na	-1
AS-NOGO-PN9	PN	9	6/20/2016	0	7/27/2016	1
AS-NOGO-PN10	PN	10	6/2/2016	0	7/26/2016	1
AS-NOGO-PN11	PN	11	6/6/2016	0	7/6/2016	0
AS-NOGO-PN12	PN	12	6/18/2016	0	7/28/2016	1
AS-NOGO-PN13	PN	13	6/19/2016	0	7/31/2016	0

Appendix B

Northern Goshawk (*Accipiter gentilis*) survey results for each Primary Sampling Unit (PSU), per year, for 2013 - 2016 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; -1 = Not Surveyed.

PSU	Stratum	Rank	2013		2014		2015		2016	
			Nest	Fledge	Nest	Fledge	Nest	Fledge	Nest	Fledge
AS-NOGO-MA1	MA	1	0	0	0	0	0	0	0	0
AS-NOGO-MA3	MA	3	0	0	0	0	0	1	0	0
AS-NOGO-MA4	MA	4	0	0	0	0	0	0	0	0
AS-NOGO-PF1	PF	1	0	0	0	0	0	0	0	0
AS-NOGO-PF2	PF	2	1	-1	1	0	0	0	0	0
AS-NOGO-PF3	PF	3	0	1	0	1	1	1	1	1
AS-NOGO-PF4	PF	4	1	1	0	0	1	1	1	0
AS-NOGO-PF5	PF	5	1	1	0	0	0	0	0	0
AS-NOGO-PF7	PF	7	0	0	0	0	0	1	0	0
AS-NOGO-PF8	PF	8	0	0	0	0	0	0	0	0
AS-NOGO-PN1	PN	1	1	-1	0	0	0	0	0	0
AS-NOGO-PN2	PN	2	0	0	0	0	1	0	0	0
AS-NOGO-PN3	PN	3	0	0	1	0	0	1	0	1
AS-NOGO-PN5	PN	5	0	1	0	0	0	0	0	1
AS-NOGO-PN6	PN	6	0	0	0	0	0	0	0	0
AS-NOGO-PN7	PN	7	0	0	0	1	0	1	0	0
AS-NOGO-PN8	PN	8	1	-1	1	0	0	0	-1	-1
AS-NOGO-PN9	PN	9	1	0	0	0	0	1	0	1
AS-NOGO-PN10	PN	10	0	0	0	0	0	0	0	1
AS-NOGO-PN11	PN	11	0	0	1	0	1	1	0	0
AS-NOGO-PN12	PN	12	1	0	0	0	0	0	0	1
AS-NOGO-PN13	PN	13	-1	-1	-1	-1	-1	-1	0	0