Northern Goshawk Monitoring in the Four Forest Restoration Initiative: 2015 Field Season Report

April, 2016

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The 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.

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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. 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 and how changes in habitat can influence those figures.

The Four Forest Restoration Initiative (4FRI) contracted Bird Conservancy of the Rockies (formally Rocky Mountain Bird Observatory) to assist in the development and implementation of Northern Goshawk monitoring within the 4FRI treatments areas. The objectives of the project are 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. To meet the objectives, we set-up a panel design aimed at surveying treatment areas before and after treatment occurred. We began monitoring in 2015 by establishing the first panel, of a three-panel design, based on areas (Task Orders) expected to be treated in the near future. We intersected 600 ha Primary Sampling Units (PSUs), originally created for the 2009 Bioregional Monitoring effort, with at least 25% of queued Task Order area within the PSU. For the 2015 effort, 18 PSUs met this criterion. We then ranked the PSUs, with a spatially balanced design using the Generalized Random Tessellation Stratified (GRTS) function (Spsurvey package) in R, from 1 to 18 with an expected survey effort of 14 PSUs.

Field technicians conducted broadcast acoustical surveys in selected PSUs during two time periods (nestling and fledgling) in the summer of 2015. Field technicians surveyed 15 PSUs twice, once between 31 May and 24 June and again between 6 July and 12 August, 2015. Technicians detected goshawks in six PSUs during the nestling period and five PSUs during the fledgling period.

Using the detections from the 15 PSUs, we determined the Northern Goshawk occupied 48% of the PSUs in the 4FRI project area with a CV of 50%. However, Bird Conservancy ran a concurrent monitoring effort in the adjacent Apache-Sitgreaves National Forests (ASNF) and were able to supplement the data with that effort. Using the combined data, we found borrowing data from the ASNF to estimate detection of the Northern Goshawk increased the precision of the occupancy estimate in the 4FRI project area. The CV of the occupancy estimate was 29 % lower when borrowing data from the ASNF (CV = 0.35) than when using only data from the 4FRI project area (CV = 0.50) with an occupancy rate in the 4FRI project area of 46%.

ACKNOWLEDGEMENTS

Dan Kipervaser of the Unites States Forest Service was essential in the development and funding of this monitoring effort. Staff within Bird Conservancy of the Rockies provided input, expertise, services and support including Rob Sparks, who created the GIS sampling frame and Chris White who facilitated the partnership between Bird Conservancy and the Four Forest Restoration Initiative. Of course field studies could not be completed without field staff. These individuals, Autumn Nielsen, Tiffany Trunnell and Amy Zimmermann 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 Chris White.

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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, Graham et al. 1992, Anderson, DeStefano 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, Graham et al. 1992, Anderson, DeStefano 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-km^2) mixed with the bird's cryptic behavior (Squires and Reynolds 1997). Therefore, the overall status of the Northern Goshawk's population remains unclear (Anderson, DeStefano 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 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.

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, Graham et al. 1992, Squires and Reynolds 1997, Reynolds and Joy 1998, Reich, Joy et al. 2004, Reynolds, Gpkham 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. 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). In 2009, the first large-scale surveys were conducted within the Southwest Bioregion (Berven 2010), providing baseline occupancy across the forests in Arizona and New Mexico. While bioregional monitoring can evaluate trends and bird responses over a large area, the effort is expensive and infrequently completed. Furthermore, local managers may have specific questions about their forests that cannot be answered at the bioregional scale.

In 2013, Bird Conservancy (formally, Rocky Mountain Bird Observatory) began monitoring the Apache-Sitgreaves National Forests (ASNF) to assess occupancy differences between habitat within and outside of the 2011 Wallow Fire burn perimeter. The Wallow fire burned over 500,000 acres within the National Forest boundary and moderately to severely burned almost 120,000 acres of ponderosa pine and mixed coniferous forests (Wadleigh 2011). Wildlife managers asked the questions; what is the status of Northern Goshawk populations in the ASNF and what is the effect of a large and destructive fire on goshawk occupancy? Bird Conservancy's continuing monitoring effort within the ASNF has addressed both questions by stratifying areas of interest based on habitat and where the fire burned. We continue to monitor the population on an annual basis to fully understand occupancy trends and use of burned areas and have found there were no appreciable differences in occupancy between the ponderosa pine and burned ponderosa pine (Berven and Pavlacky 2016).

The Four Forest Restoration Initiative (4FRI) contracted Bird Conservancy of the Rockies to develop and implement Northern Goshawk monitoring, using the technical guide as a reference. The 4FRI is a collaborative effort to restore the Apache-Sitgreaves, Coconino, Kaibab and Tonto National Forests to their fire-adapted ecological state through restoration projects, including, but not limited to, thinning and prescribed fire. The restored forests should promote healthy forests capable of supporting native flora and fauna while reducing the risk of severe wildfires and its impact on local communities (Governor's Forest Health Councils 2007). Adaptive management is a critical part of the restoration process and the Statewide Strategy for Restoring Arizona's Forests (2007) specifically calls for ecological monitoring as part of the process to guide future management practices. The Northern Goshawk is an apt species to monitor because it is a USFS species of concern, an indicator species and sensitive to management practices.

The contract between these two entities is advantageous for 4FRI 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 (Berven 2010), and continues the annual monitoring effort in the ASNF (Berven and Pavlacky 2016). We used the Bioregional design so results can be compared year-to-year and across different areas of inference. Lastly, if monitoring efforts take place during the same season in similar habitat, we can augment smaller survey efforts with larger efforts to increase precision in occupancy estimates.

METHODS

Study Design

The sampling frame consists of rotating panels that are to be treated and monitored in future years. For example, the sampling frame for this design included 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 sample the Primary Sampling Units (PSU) before and after the 4FRI treatments in a rotating panel design (Table 1). For example, in year 2015, Panel 1 would be monitored before treatment and in a subsequent year, Panel 1 will be monitored after treatment, Panel 2 will be monitored before treatment, and the before and after monitoring would be replicated in subsequent years. A potential sampling schedule was to sample 14 PSUs in each panel and year for a cumulative sample size n = 42 before treatment and n = 42 after treatment.

Table 1. Before and after rotating panel design for three sets of task orders.

Year	Panel 1	Panel 2	Panel 3
1	X		
2	X	X	
3		X	X
4			X

The schedule of repeated surveys of the PSUs corresponded to a double sampling design with two survey occasions (MacKenzie, Nichols et al. 2006). In the ASNF monitoring effort, 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 and 2015, we used the standard sampling design where all PSUs received a second visit because of low detection rates during the nestling season in 2014 and found the resurvey effort to be no costlier than surveying only 50% of sites with detections.

To maintain consistency and the ability to relate outcomes to the Bioregional and ASNF goshawk monitoring efforts, we used the same Bioregional grid for the 4FRI monitoring efforts. In 2009, Bird Conservancy created PSUs using protocols described in the “Northern Goshawk Inventory and Monitoring Technical Guide” (Woodbridge and Hargis 2006). Using ArcGIS (ESRI 2005), the region-wide grid was creating using 600.25ha PSUs overlaid onto a USFS administrative border layer for the USFS Southwest Region. The PSU’s center point was used to determine if the unit was included in the sampling effort; the center point needed to be within the USFS administrative boundary. The USFS administrative boundary layer did not delineate non-USFS property owners within the boundary and thus, private lands were included as part of the sampling frame. We implemented habitat and survey-cost stratification to increase the effectiveness of surveying over a large geographical area. In 2009, the first stratification was between habitat classes, 1) Primary habitat consisted of Ponderosa pine or mixed coniferous forests and 2) Secondary habitat consisted of sub-alpine forests or pinyon-juniper woodlands, using the General Terrestrial Ecosystem Survey (GTES) data layer (United States Forest Service. Southwest Region. 2001). Any PSU containing a minimum of 20% of the woodland (4), montane (5), upper-montane (6) and sub-alpine (7) climate classes from the GTES was included in the Bioregional sampling frame. We then divided the sampling frame into grids with a minimum of 20% montane (climate class 5, ponderosa pine) and upper-montane (climate class 6, mixed-conifer) vegetation and all other grids with dominant cover of woodland (climate class 4, pinyon-juniper) and subalpine (climate class 4, spruce-fir) vegetation (Figure 1). The study area for the 2015 field effort includes Task Orders for the Hart Prairie, Wing Mountain and

Clints SW areas within the Four Forest Restoration Initiative in Arizona (Figure 2). A PSU was including in the sampling frame if at least 25% of the PSU intersected the Task Order footprint. To order PSUs within the sampling frame, we used a spatially balanced study design using the generalized random-tessellation stratification (GRTS) function (Spsurvey package) in R (Stevens 2004) as seen in Figure 2.

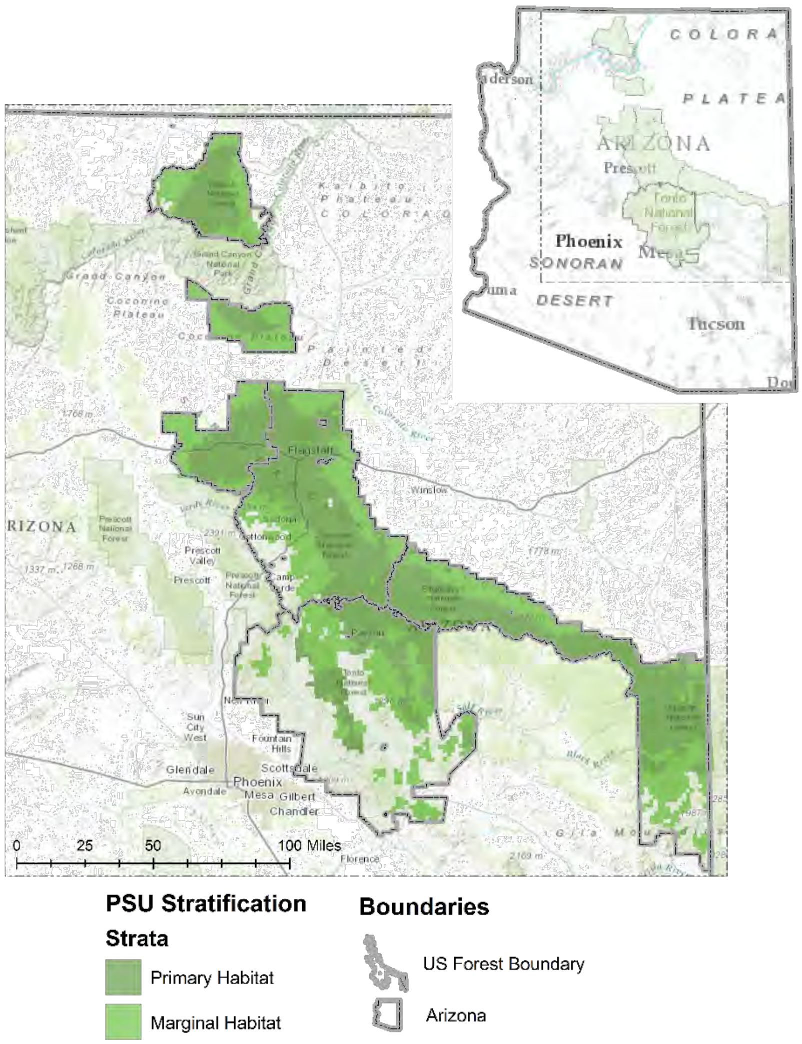

Figure 1. Northern Goshawk Monitoring in the Southwest United States 2009 stratification between primary and secondary habitat within the Four Forest Restoration Initiative National Forests.

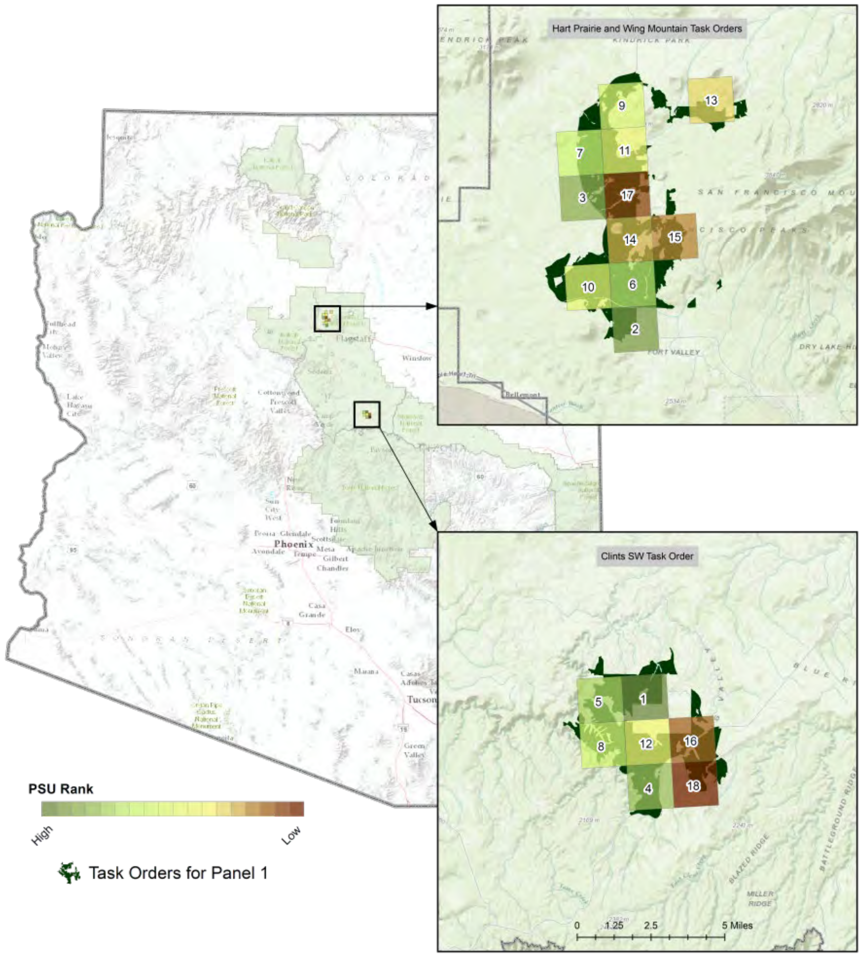

Figure 2. Primary Sampling Unit (PSU) ranking for Northern Goshawk (*Accipiter gentilis*) surveys for the Hart Prairie, Wing Mountain and Clints SW Task Orders within the Four Forest Restoration Initiative, Arizona, 2015.

After the PSUs were randomly selected for survey, a grid of call station points was added to each unit using ArcGIS. We overlaid 120 call stations on 10 transect lines (each containing 12 stations spaced 200 m apart) on each PSU (Figure 3). 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. Call stations in unsuitable locations (slope >36°, >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 a 30 x 30 m LANDFIRE vegetation cover-type layer(LANDFIRE 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. 2012). All call stations within the PSU were included on maps but were labeled according to suitability criteria (Figure 3). Using ArcGIS, field maps were created showing PSU, Task Order 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.

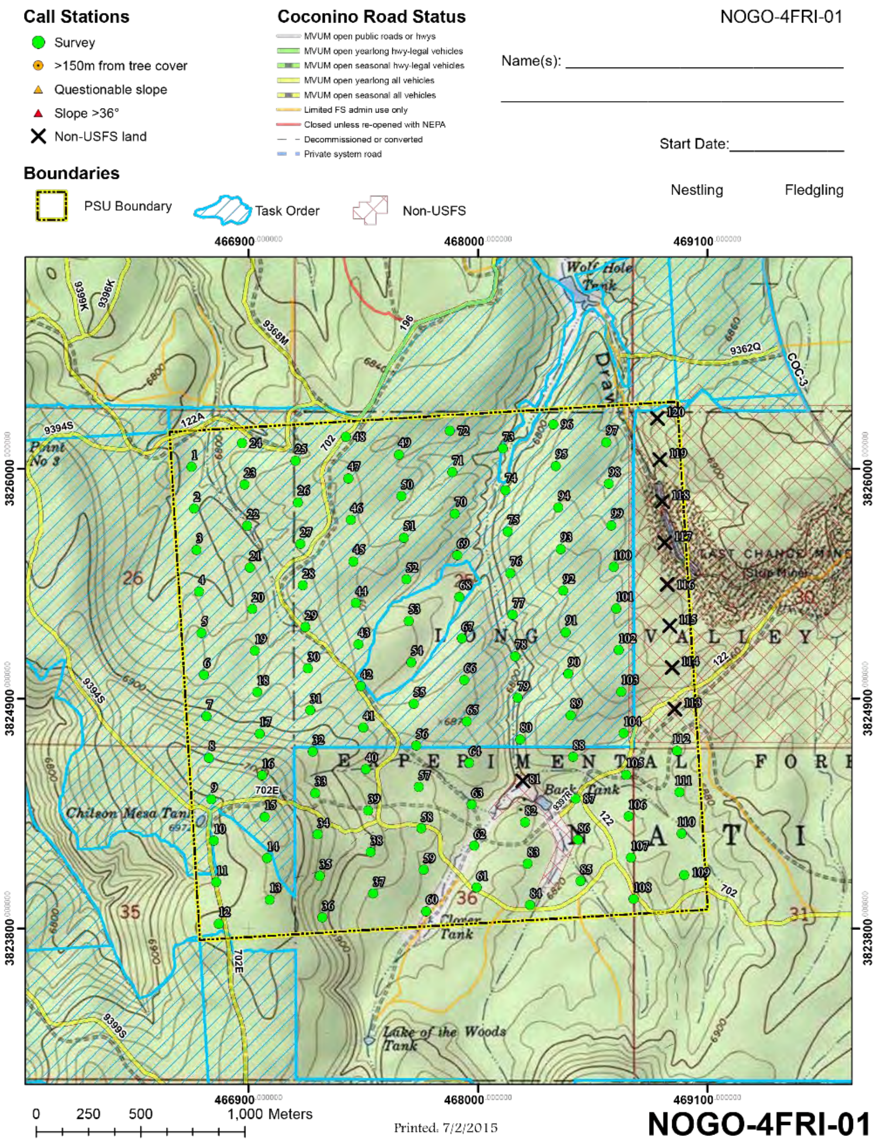

Figure 3. An example of a Primary Sampling Unit (PSU) map used by technicians throughout the field season to survey for Northern Goshawks (*Accipiter gentilis*) for the Four Forest Restoration Initiative, Arizona, 2015.

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 three times (and the circle completed), technicians waited, watched and listened for one minute then repeated the cycle. After the technicians made two complete circles, they waited, watched and listened for two minutes. Technicians recorded any significant findings and time spent at each call station on a standardized field form. After completing call procedures at a call station where there was no detection, 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. Technicians started survey efforts within the Task Order portions of the PSU, if no detection was made within the Task Order boundary, technicians would move onto areas within the PSU but outside of the Task Order. 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.

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 Bird Conservancy personnel in the last week of May 2015.

Occupancy estimation

We estimated the site occupancy of the Northern Goshawk in the Four Forest Restoration Initiative (4FRI) project area using two analysis methods. The first method used only data from the 4FRI project area (N = 15) and the second method borrowed data collected in the Apache-Sitgreaves National Forest (ASNF) in 2015 (N = 21) to improve estimates the of detection for the Northern Goshawk (MacKenzie, Nichols et al. 2005). For the first analysis method, we evaluated 4 models for estimating the probability of detection, including a model that held detection constant [p(.)], and models that allowed detection to vary by season [nestling and fledging periods, $p(t)$], survey effort [p(Effort)], and effort and season [p(Effort+ t)]. We measured survey effort as the percentage of available call point stations in suitable habitat within the PSUs ($\bar{x}$ = 72 %; SD = 26; range = 9 %, 100 %).

For the second analysis method, we evaluated 3 additional models that allowed detection to vary by region [4FRI and ASNF, p(Region)], region and season [p(Region + t)], region and effort [p(Region + Effort)], for a total of 7 models. All 7 models included the effect of strata on occupancy [ψ(Strata)], allowing separate estimates of occupancy for the 4FRI project area, as well at the primary, primary-fire, and secondary strata in the ASNF. We combined the strata-level estimates of occupancy in the ASNF using the area weighted mean and delta method (Powell 2007). We estimated the probabilities of detection and occupancy for the Northern Goshawk in the 4FRI project area and ASNF using the MacKenzie et al. (2002) occupancy model. We fit the occupancy model using the R interface for program MARK (RMARK Version 2.1.13; R Version 3.2.2, www.R-project.org; MARK Version 8.0, www.phidot.org; accessed 23 December 2015).

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) for models 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 models i and j given the data by evidence ratios (w_i / w_j). We model averaged the predictions and parameter estimates, and estimated unconditional standard errors, 95% Confidence Intervals (CI) and Coefficients of Variation (CV) for all models in the candidate set (Burnham and Anderson 2002). We evaluated the effects sizes for variables using beta parameter estimates with respect to conditional CIs (Burnham and Anderson 2002).

RESULTS

Nestling surveys began on 31 May 2015. Hatching was estimated to have occurred late-May to early-June 2015. Northern Goshawks in monitored nests began leaving the immediate nest area on or close to 4 July 2015. Fledgling surveys began 6 July and continued until all PSUs were resurveyed (5 August 2015).

We surveyed fifteen PSUs one time (Figure 4, Appendix A) during the nestling survey window and we re-surveyed all PSUs during the fledgling survey window. The "Northern Goshawk Inventory and Monitoring Technical Guide" recommends resurveying a portion of the PSUs with a detection to reduce costs. However, that recommendation is based on a very large sample size and we have found in the Apache-Sitgreaves National Forests annual survey effort that re-surveying all PSUs during the fledgling survey window produces better estimates but does not add a significant cost to the project. Technicians made a total of 11 goshawk detections throughout the field season (Figure 5); 6 during the nestling surveys and 5 during the fledgling surveys.

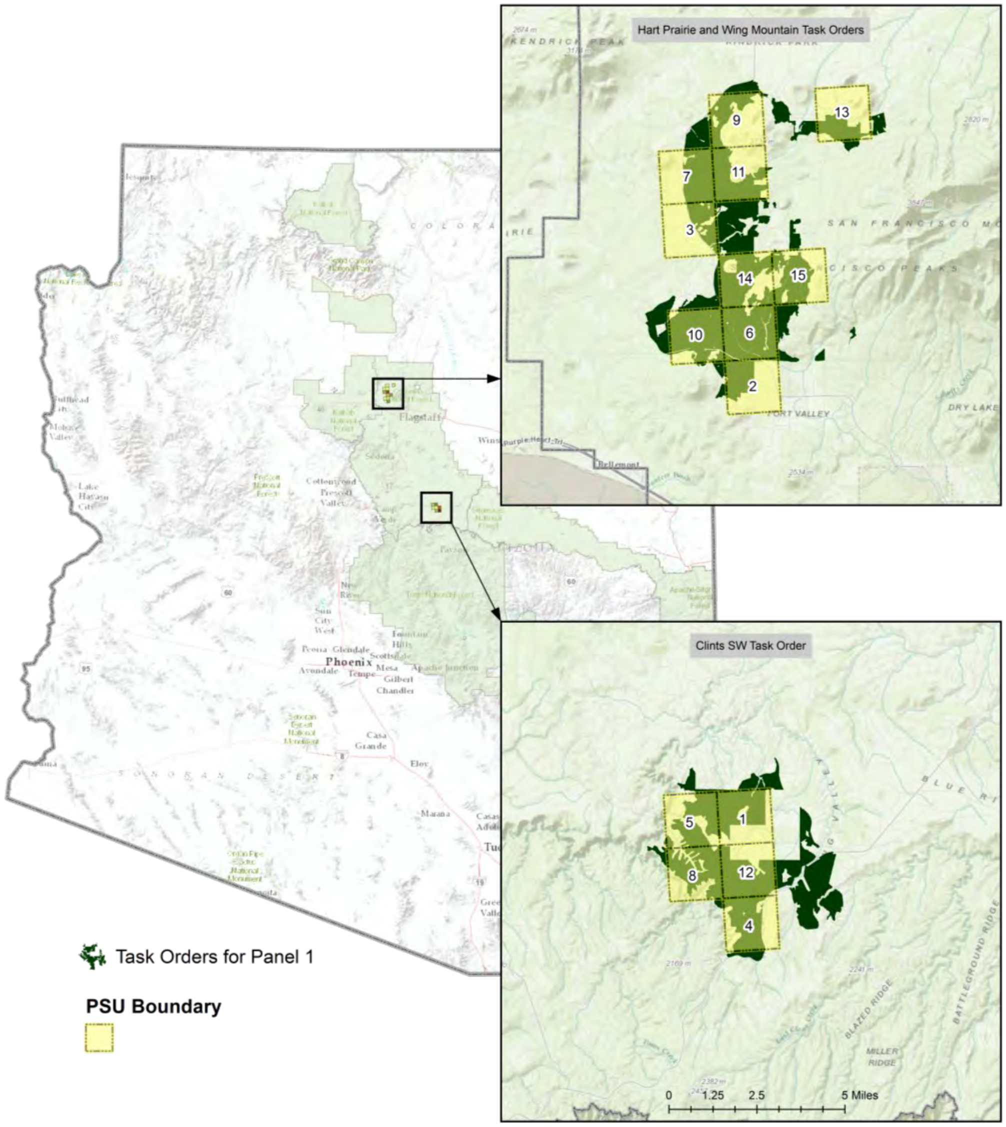

Figure 4. Primary Sampling Unit (PSU) surveyed for Northern Goshawk (*Accipiter gentilis*) occupancy for the Four Forest Restoration Initiative, Arizona, 2015.

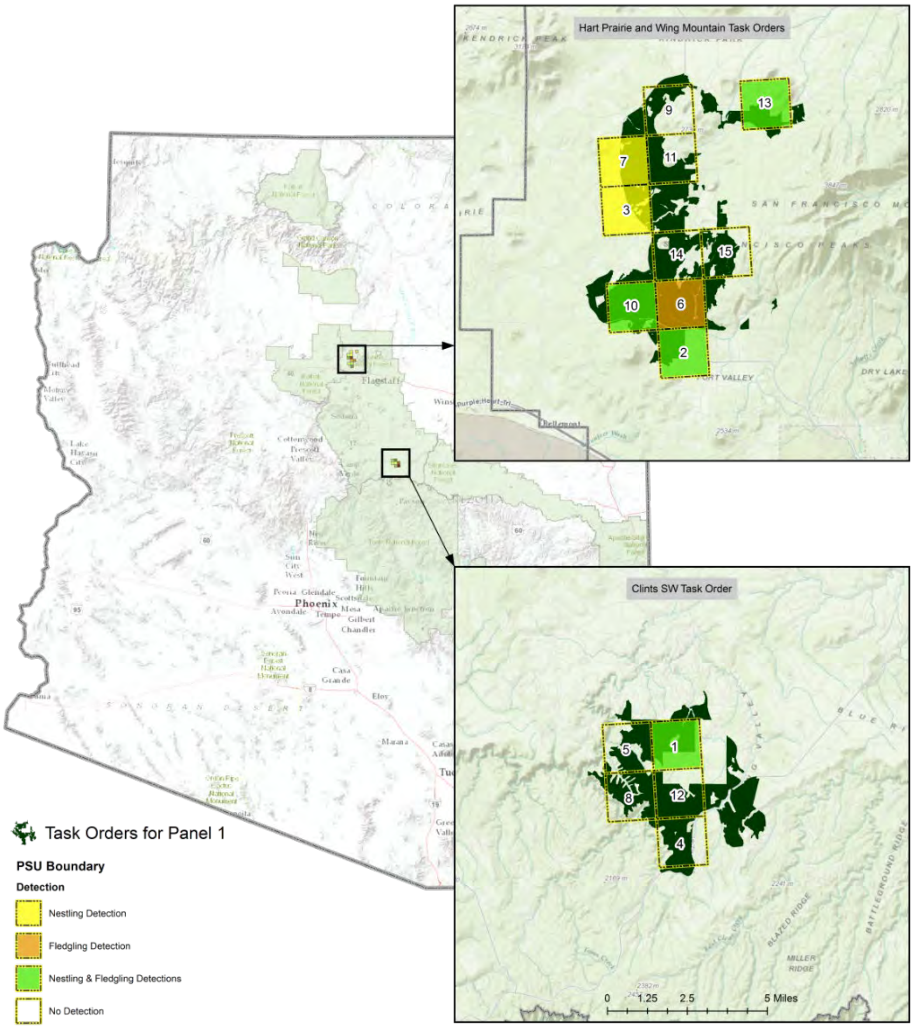

Figure 5. Primary Sampling Unit (PSU) with Northern Goshawk (*Accipiter gentilis*) detections within the Four Forest Restoration Initiative, Arizona, 2015.

The best approximating model for the occupancy of the Northern Goshawk using only data from the 4FRI project area included the effect of survey effort on detection (Table 2). The evidence ratio indicated the best model with the effect of survey effort was ~4 times more plausible than the second best model with a constant rate of detection (Table 2). The detection rate of the Northern Goshawk declined with increasing survey effort, but the CI for the effect narrowly covered 0, indicating a small effect of survey effort on detection (Table 3). Using only data from the 4FRI project data, the detection rate of the Northern Goshawk was 78 % with a CV of 58 % (Table 4). The Northern Goshawk occupied 48 % of the PSUs in the 4FRI project area with a CV of 50 % (Table 4).

The best model for the occupancy of the Northern Goshawk using data from the ASNF to augment the analysis included the effect of region on detection (Table 2). The evidence ratio indicated the best model with the effect of region was ~2 times more plausible than the second best model with a constant rate of detection and ~3 times more plausible than the third best model with the effect of effort (Table 5). The detection rate of the Northern Goshawk was lower in the ASNF than the 4FRI project area, and the CI for the effect excluded 0, indicating a large effect of region on detection (Table 6). Using data from the ASNF to augment the analysis, the detection rate of the Northern Goshawk in the 4FRI project area during the fledgling period was 71 % with a CV of 26 % (Table 7). The Northern Goshawk occupied 46 % of the PSUs in the 4FRI project area with a CV of 35 % (Table 7). The detection rate during the fledgling period was 37 % lower in the ASNF ($p = 0.44$) than in the 4FRI project area ($p = 0.71$), whereas the occupancy rate was 64% greater in the ASNF (75 %) than in the 4FRI project area (46 %, Table 7).

We found that borrowing data from the ASNF to estimate detection of the Northern Goshawk increased the precision of the occupancy estimate in the 4FRI project area. The CV of the occupancy estimate was 29 % lower when borrowing data from the ASNF (CV = 0.35, Table 7) than when using only data from the 4FRI project area (CV = 0.50, Table 4). Borrowing data from the ASNF had only a small effect on the point estimate of occupancy for the 4FRI project area. The occupancy rate of the 4FRI project area was 4 % lower when borrowing data from the ASNF ($\psi = 0.46$, Table 7) than when using only data from the 4FRI project area ($\psi = 0.48$, Table 4).

Table 2. Model selection for estimating the detection and occupancy rates of the Northern Goshawk in the Four Forest Restoration Initiative project area, 2015, Arizona, USA. The model selection metrics are the minimized -2 log-likelihood of the model [-2log(L)], number of parameters (K), Akaike Information Criterion adjusted for sample size (AIC_c), change in AIC_c (ΔAIC_c) and AIC_c weight (w_i). All models with $\Delta AIC_c < 4$ are shown.

Model	-2log(L)	K	AIC_c	ΔAIC_c	w_i
p(Effort) ψ(.)	26.21	3	32.96	0.00	0.680
p(.) ψ(.)	31.24	2	35.60	2.64	0.182

Table 3. Parameter estimates, standard errors (SE), coefficients of variation (CV), and lower and upper 95% confidence limits (LCL and UCL respectively) from the highest ranking detection model for the Northern Goshawk in the Four Forest Restoration Initiative project area, 2015, Arizona, USA.

Parameter	Estimate	SE	CV	LCL	UCL
Intercept	6.21	5.80	0.93	-5.16	17.58
Effort	-7.31	5.20	0.71	-17.51	2.89

Table 4. Model averaged estimates of detection, occupancy, unconditional standard errors (SE), coefficients of variation (CV), and lower and upper 95% confidence limits (LCL and UCL respectively) for the Northern Goshawk in the Four Forest Restoration Initiative project area, 2015, Arizona, USA.

Parameter	Estimate	SE	CV	LCL	UCL
Detection	0.763	0.439	0.576	0.026	0.998
Occupancy	0.475	0.237	0.499	0.084	0.887

Table 5. Model selection for estimating the detection and occupancy rates of the Northern Goshawk in the Four Forest Restoration Initiative project area using data from the Apache-Sitgreaves National Forest to augment the analysis, 2015, Arizona, USA. The model selection metrics are the minimized -2 log-likelihood of the model [-2log(L)], number of parameters (K), Akaike Information Criterion adjusted for sample size (AICc), change in AICc (ΔAICc) and AICc weight (wi). All models with ΔAICc < 4 are shown.

Model	-2log(L)	K	AIC_c	ΔAIC_c	w_i
p(Region) ψ(Strata)	82.08	6	96.97	0.00	0.350
p(.) ψ(Strata)	86.05	5	98.05	1.08	0.204
p(Effort) ψ(Strata)	84.09	6	98.99	2.02	0.128
p(Region + t) ψ(Strata)	81.23	7	99.23	2.26	0.113
p(Region + Effort) ψ(Strata)	81.71	7	99.71	2.74	0.089
p(t) ψ(Strata)	85.22	6	100.12	3.15	0.073

Table 6. Parameter estimates, standard errors (SE), coefficients of variation (CV), and lower and upper 95% confidence limits (LCL and UCL respectively) from the highest ranking detection model for the Northern Goshawk in the Four Forest Restoration Initiative project area using data from the Apache-Sitgreaves National Forest to augment the analysis, 2015, Arizona, USA.

Parameter	Estimate	SE	CV	LCL	UCL
Intercept	1.39	0.87	0.62	-0.32	3.09
Apache-Sitgreaves	-2.10	0.99	0.47	-4.05	-0.14

Table 7. Model averaged estimates of detection, occupancy, unconditional standard errors (SE), coefficients of variation (CV), and lower and upper 95% confidence limits (LCL and UCL respectively) for the Northern Goshawk in the Four Forest Restoration Initiative project and Apache-Sitgreaves National Forest, 2015, Arizona, USA.

Project area					
Parameter	Estimate	SE	CV	LCL	UCL
Four Forest Restoration Initiative					
Detection: nestling	0.678	0.194	0.286	0.269	0.924
Detection: fledgling	0.705	0.186	0.264	0.293	0.933
Occupancy	0.457	0.162	0.353	0.169	0.762
Apache-Sitgreaves National Forest					
Detection: nestling	0.412	0.163	0.395	0.158	0.724
Detection: fledgling	0.443	0.171	0.387	0.169	0.757
Occupancy	0.749	0.231	0.309	0.211	0.971

DISCUSSION AND RECOMMENDATIONS

Nationally, the status of the Northern Goshawk remains of interest because insufficient data exist on their population. USFS wildlife officials classified the Northern Goshawk as a species of special interest within the Southwest Region. 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 Bioregional Monitoring field season 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 at a large scope. However, there remains a need to develop and implement local, smaller-scope Northern Goshawk monitoring to provide reliable data for the evaluation of the species' status within smaller management units and if and how management practices influence goshawk occupancy. This long-term monitoring effort will assess the 4FRI's restoration projects impact on goshawk occupancy and help guide future management practices.

The occupancy estimates determined by the 2015 sampling effort provides a baseline and pre-treatment status of goshawks within initial management units in the 4FRI area. We determined 46% of suitable habitat within the management areas is occupied by goshawks. These estimates were fine-tuned with the additional survey effort from the neighboring Apache-Sitgreaves National Forests field season. However, a single year of monitoring represents only a small piece of information and is difficult to use for comparisons because annual goshawk breeding success varies significantly among years (Reich, Joy et al. 2004, Patla 2005, MacKenzie, Nichols et al. 2006). Therefore, the best practice is to continually and consistently monitor populations, whether it be at the bioregional or forest scale.

The effect of management practices and fires (whether natural or prescribed) on goshawk populations remains an important question and until recently, there has been little research on how these conditions affect goshawk populations (Stone 2013). One such example is that the ASFS monitoring effort cannot address if goshawk occupancy in the Wallow Fire burn area is significantly different from before the burn because there was no forest-wide monitoring prior to the Wallow Fire. Fortunately, the 4FRI recognized the importance of monitoring before and after treatment and, as part of the proposal for goshawk monitoring, will do this by using a panel design. The next steps for this project include 1) surveying Task Order 1 after treatment is concluded; 2) surveying two additional panels (treatment areas treated within the same year) before treatments are started; 3) surveying each additional panel after treatment is concluded; 4) at the conclusion of the monitoring effort, evaluate the effects of landscape heterogeneity, and thus, the 4FRI's restoration efforts on Northern Goshawk occupancy. Timing on the future goshawk survey efforts is flexible and nothing is scheduled until, at least, 2017 for two reasons, 1) Task Order 1 will need to be completed and will need time to recover from treatments and 2) new Task Orders treatments require significant coordination with other stakeholders within the 4FRI area.

LITERATURE CITED

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

Anderson, D. E., S. DeStefano, M. I. Goldstein, K. Titus, D. C. Crocker-Bedford, J. J. Keane, R. G. Anthony and R. N. Rosenfield (2005). "Technical review of the status of northern goshawks in the Western United States." Journal of Raptor Research **39**(3): 192-209.

Berven, J. M. and D. C. Pavlacky (2016) "Northern Goshawk Monitoring in the Apache-Sitgreaves National Forests: 2015 Field Season Report." Bird Conservancy of the Rockies, 25.

Berven, J. M., Pavlacky, D.C. (2010) "Northern Goshawk Monitoring in the Southwest United States: 2009 Field Season Report." Rocky Mountain Bird Observatory, 24.

Burnham, K. P. and D. R. Anderson (2001). "Kullback-Leibler Information as a basis for strong inference in ecological studies." Wildlife Research **28**(2): 111-119.

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

Governor's Forest Health Councils (2007). The Statewide Strategy for Restoring Arizona's Forests. E. Aumack, T. Sisk, and J. Palumbo. Phoenix, AZ, State of Arizona.

Hurvich, C. M. and C. L. Tsai (1989). "Regression and time-series model selection in small samples." Biometrika **76**(2): 297-307.

Kullback, S. and R. A. Leibler (1951). "On information and sufficiency." Annals of Mathematical Statistics **22**(1): 79-86.

LANDFIRE (2012). Existing Vegetation Cover layer., U.S. Department of Interior, Geological Survey. **1.1.0**.

MacKenzie, D. I. and J. D. Nichols (2004). "Occupancy as a surrogate for abundance estimation." Animal biodiversity and conservation **27**(1): 461-467

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. Royle and C. A. Langtimm (2002). "Estimating site occupancy rates when detection probabilities are less than one." Ecology **83**(8): 2248-2255.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey and J. E. Hines (2006). Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Burlington, VT., Elsevier.

MacKenzie, D. I., J. D. Nichols, N. Sutton, K. Kawanishi and L. L. Bailey (2005). "Improving inferences in population studies of rare species that are detected imperfectly." Ecology **86**(5): 1101-1113.

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**(3): 324-334.

Powell, L. A. (2007). "Approximating variance of demographic parameters using the delta method: a reference for avian biologists." The Condor **109**(4): 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**(1-2): 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**(4): 1047-1055.

Reynolds, R. T., R. T. Graham, M. H. Reiser, R. L. Bassett, P. L. Kennedy, D. A. Boyce Jr., G. Goodwin, R. Smith and E. L. Fisher (1992). Management recommendations for the northern goshawk in the Southwestern United States. General Technical Report RM-217. Fort Collins, CO, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.

Reynolds, R. T. and S. M. Joy (1998). Distribution, territory occupancy, dispersal, and demography of northern goshawks on the Kaibab Plateau, Arizona. Final Report for Arizona Game and Fish Heritage Project Number 194045.
Squires, J. R. and R. T. Reynolds (1997). Northern Goshawk (Accipiter gentilis). The Birds of North America. A. a. F. Gill, The Academy of Natural Sciences. Philadelphia, PA and The American Ornithologists' Union. Washington, DC, U.S.A. **No. 298**.
Squires, J. R. and L. F. Ruggiero (1996). "Nest-Site Preference of Northern Goshawks in Southcentral Wyoming." The Journal of Wildlife Management **60**(1): 170-177.
Stevens, D. L., Jr. and A. R. Olsen (2004). "Spatially balanced sampling of natural resources." Journal of the American Statistical Association **99**(465): 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. Federal Register. **62:** 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. Federal Register. **63:** 35183–35814.
United States Forest Service (1991). Planning for management and recovery. Washington, DC: U.S, Department of Agriculture, Forest Service. **FSM 2672 Amend. 2600-91-4**.
United States Forest Service (1995). Threatened, endangered and sensitive plants and animals. Washington, DC, U.S. Department of Agriculture, Forest Service. **FSM 2670 Amend. 2600-95-7**.
United States Forest Service. Southwest Region. (2001). General Terrestrial Ecosystem Survey, Earth Data Analysis Center.
United States Forest Service. Southwest Region. (2012). Surface Ownership, USFS Southwestern Regional Office.
Wadleigh, L. (2011). Wallow Fire 2011, Fire/Fuels Report, Apache-Sitgreaves National Forests. L. S. E. R. R. A. Team, USDA Forest Service, Southwest Region.
Woodbridge, B. and C. D. Hargis (2006). Northern Goshawk Inventory and Monitoring Technical Guide. General technical report WO 71. Washington D.C., United States Dept. of Agriculture, Forest Service.

APPENDIX A

Northern Goshawk (*Accipiter gentilis*) survey results for each Primary Sampling Unit (PSU) visited during the Nestling (31 May – 28 July) and Fledgling seasons (6 July – 12 August), 2015 in the Four Forest Restoration Initiative, Ariz. Detection Results: 1 = Surveyed with Detection; 0 = Surveyed without Detection.

		Nestling Season		Fledgling Season	
PSU	Rank	Completion Date	Results	Completion Date	Results
NOGO-4FRI-01	1	6/7/2015	1	7/13/2015	1
NOGO-4FRI-02	2	6/1/2015	1	7/25/2015	1
NOGO-4FRI-03	3	6/2/2015	1	7/14/2015	0
NOGO-4FRI-04	4	6/9/2015	0	7/15/2015	0
NOGO-4FRI-05	5	6/21/2015	0	8/2/2015	0
NOGO-4FRI-06	6	6/3/2015	0	7/8/2015	1
NOGO-4FRI-07	7	6/13/2015	1	7/11/2015	0
NOGO-4FRI-08	8	6/22/2015	0	8/3/2015	0
NOGO-4FRI-09	9	6/13/2015	0	7/20/2015	0
NOGO-4FRI-10	10	6/15/2015	1	7/6/2015	1
NOGO-4FRI-11	11	6/17/2015	0	7/20/2015	0
NOGO-4FRI-12	12	6/23/2015	0	8/5/2015	0
NOGO-4FRI-13	13	6/24/2015	1	7/26/2015	1
NOGO-4FRI-14	14	7/1/2015	0	7/22/2015	0
NOGO-4FRI-15	15	7/2/2015	0	7/30/2015	0