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NORTHERN GOSHAWK MONITORING IN THE WESTERN GREAT LAKES BIOREGION

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Abstract.—Uncertainties about factors affecting Northern Goshawk (*Accipiter gentilis*) ecology and the status of populations have added to the challenge of managing this species. To address data needs for determining the status of goshawk populations, Hargis and Woodbridge (2006) developed a bioregional monitoring protocol based on estimating occupancy. The goal of our study was to implement this protocol and collect data to determine goshawk population status in the western Great Lakes (WGL) bioregion, which encompasses portions of Minnesota, Wisconsin, and Michigan, and is a mixture of private and public property. We used 366 goshawk nest locations obtained between 1979 and 2006 throughout the WGL bioregion to develop a model of landscape use consisting of forest canopy cover and land-cover covariates. We then used the model to develop a stratified sampling design for selecting 600-ha Primary Sampling Units (PSUs) to survey for goshawks. Project collaborators surveyed 86 PSUs for goshawk presence using broadcasted calls twice between mid-May and mid-August 2008, and recorded 30 goshawk detections in 21 different PSUs. Seventy-four percent of detections occurred at call stations with canopy closure >75%. Goshawk detection probabilities were 0.549 ± 0.118 (standard error) for the first visit to PSUs and 0.750 ± 0.126 for the second visit. We estimated the proportion of PSUs occupied by goshawks as 0.266 ± 0.047, which corresponded to 5184 ± 914 PSUs occupied by goshawks in our study area and suggested that goshawks are widely, but sparsely, distributed throughout the WGL bioregion.

Key Words: *Northern Goshawk*; Accipiter gentilis; *occupancy; population monitoring; raptors; stratified sampling; surveys; western Great Lakes bioregion.*

MONITOREO DE *ACCIPITER GENTILIS* EN LA BIOREGIÓN DEL OESTE DE LOS GRANDES LAGOS

Resumen.—La incertidumbre acerca de los factores que afectan la ecología de *Accipiter gentilis* y el estado de sus poblaciones se han añadido al reto del manejo de esta especie. Para hacer frente a las necesidades de datos para determinar el estado de las poblaciones de *A. gentilis*, Hargis y Woodbridge (2006) desarrollaron un protocolo de monitoreo bioregional basado en estimados de ocupación. El objetivo de nuestro estudio fue la implementación de este protocolo y colectar datos para determinar el estado de la población de *A. gentilis* en la bioregión del oeste de los Grandes Lagos (OGL), que abarca partes de Minnesota, Wisconsin y Michigan, y es una mezcla de propiedades públicas y privadas. Utilizamos 366 sitios de nidos de *A. gentilis* obtenidos entre 1979 y 2006 en toda la bioregión del OGL para desarrollar un modelo de uso del paisaje que consistió en covariables de la cobertura de dosel de bosque y cobertura de suelo. A continuación, utilizamos el modelo para desarrollar un diseño de muestreo estratificado para seleccionar 600 ha de Unidades Primarias de Muestreo (UPM) para muestrear individuos de *A. gentilis*. Los colaboradores del proyecto muestrearon 86 UPM's para determinar la presencia de estos halcones utilizando emisión de llamadas grabadas entre mediados de mayo y mediados de agosto de 2008, y registraron 30 detecciones de

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A. gentilis en 21 UPM's diferentes. Setenta y cuatro por ciento de las detecciones se produjeron en las estaciones de llamada con cobertura de dosel de >75%. La probabilidad de detección de los halcones fue de 0.549 ± 0.118 (error estándar) para la primera visita a una UPM y de 0.750 ± 0.126 para la segunda visita. Estimamos la proporción de PCU's ocupadas por *A. gentilis* en 0.266 ± 0.047, que correspondió a 5.184 ± 914 PSU ocupadas por *A. gentilis* en nuestra área de estudio, y sugirió que los individuos de *A. gentilis* se distribuyen ampliamente pero de forma dispersa por toda la bioregión del OGL.

[Traducción del equipo editorial]

The challenge of managing forest resources for Northern Goshawk (*Accipiter gentilis*; hereafter, ''goshawk'') populations in North America has involved maintaining suitable nesting and foraging habitat while simultaneously allowing for timber harvest and other activities (Squires and Kennedy 2006). Goshawks have been associated with mature forests because of their observed use of stands with relatively large trees and high canopy closure (Squires and Reynolds 1997, Boal et al. 2005). However, much regional variation exists in tree species and sizes used for nests (Siders and Kennedy 1994, Squires and Ruggiero 1996, Boal et al. 2006). Goshawk diets are diverse across their breeding range (Doyle and Smith 2001, Salafsky et al. 2005, Smithers et al. 2005), and suitable foraging habitat for goshawks may encompass a broader range of forest types and structure than that for nests (Boal et al. 2005, Reynolds et al. 2008). Much of the literature on goshawk nesting, foraging, movements, and demography has come from research in the southwestern and western United States (e.g., Andersen et al. 2005, Fairhurst and Bechard 2005, Reynolds et al. 2005, Wiens et al. 2006b), and greater uncertainty about their ecology remains elsewhere in North America.

Knowledge of large-scale, regional trends in goshawk populations is needed to evaluate whether populations are decreasing, stationary, or increasing (Andersen et al. 2005). To achieve this, Woodbridge and Hargis (2006) developed a goshawk monitoring protocol for use in designing monitoring plans for 10 ''bioregions'' throughout the country. The objectives of bioregional monitoring were to: (1) estimate the frequency of occurrence of goshawks within each bioregion; (2) assess changes in the frequency of occurrence over time, and (3) determine whether any changes in the frequency of occurrence were related to habitat change (Hargis and Woodbridge 2006). A regional scale for goshawk monitoring was suggested because surveying smaller land units such as individual national forest lands is problematic owing to ecological and sampling reasons (Hargis and Woodbridge 2006). Goshawks are highly mobile and the interbreeding population spans a regional scale. Obtaining an adequate sample size within one forest to determine a change in population abundance with sufficient power is costly (Hargis and Woodbridge 2006). The goshawk monitoring protocol (Hargis and Woodbridge 2006) addresses study design recommendations of Pollock et al. (2002) by affording inference to the entire sampled portion of the bioregion and estimating detection probabilities using double sampling.

Information on goshawk ecology is limited and the population status of the species is unknown within the western Great Lakes (WGL) bioregion that encompasses portions of Minnesota, Wisconsin, and Michigan (Boal et al. 2006). The goals of our study included addressing data needs for determining goshawk population status in the WGL bioregion using the goshawk monitoring protocol of Hargis and Woodbridge (2006) and concurrently collecting habitat-use information. We first used existing goshawk nest location data from the WGL bioregion to develop a model of goshawk landscape use consisting of habitat attribute covariates derived from Geographic Information System (GIS) layers. We then used the model to assist in developing a stratified random sampling design for selecting sampling units for the bioregional survey. Finally, we completed the bioregional survey in 2008 and estimated goshawk occupancy and detection probabilities for the portion of the bioregion that we surveyed. This work provides the first estimate of goshawk occupancy for the WGL population and offers insights into the potential for monitoring goshawks and other raptors in other regions of North America.

METHODS

Study Area. The WGL bioregion consists of lands in northeastern and north-central Minnesota, northern Wisconsin, and northern Michigan (Woodbridge and Hargis 2006) and encompasses the approximate goshawk breeding range based on historical locations of nests (Fig. 1). Because funding limitations precluded surveying the entire breeding range, we delineated our study area based

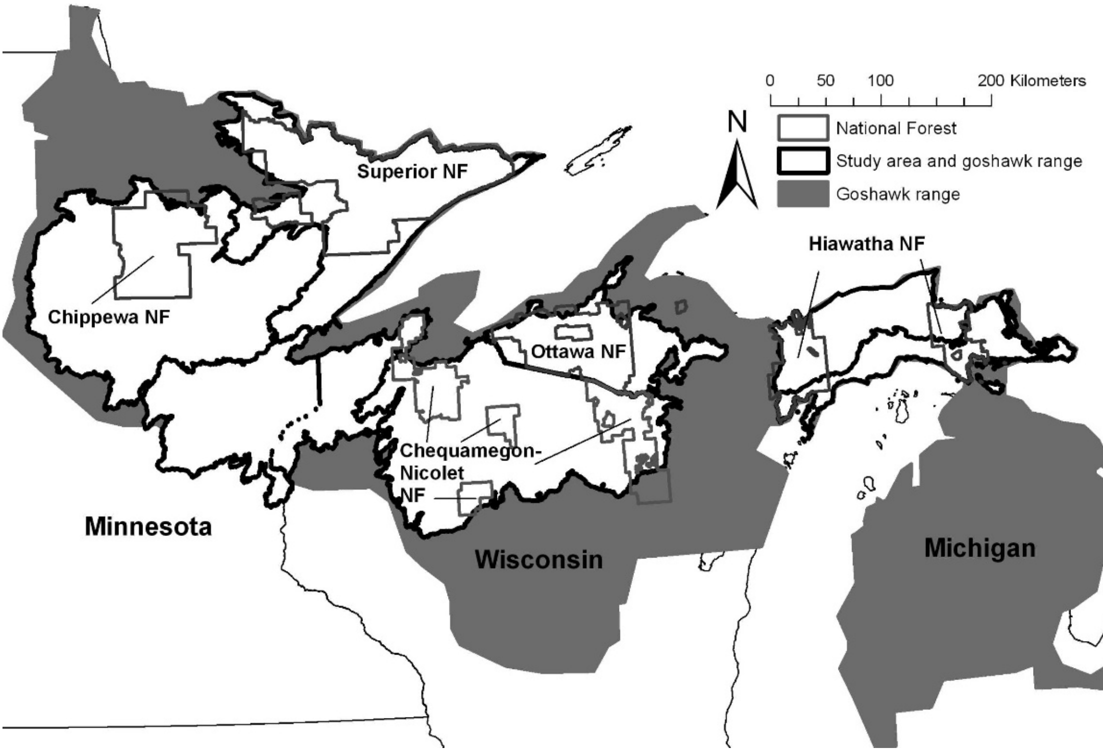


Figure 1. The Northern Goshawk breeding range that includes the study area in the western Great Lakes bioregion, encompassing portions of Minnesota, Wisconsin, and Michigan. The five national forests (NF) in the study area were the Chippewa NF and Superior NF in Minnesota, the Chequamegon-Nicolet NF in Wisconsin, and the Ottawa NF and Hiawatha NF in Michigan.

on seven ecological subregions (McNab et al. 2007) totaling 135 074 km^2 (Fig. 1) within the Laurentian Mixed Forest Province Ecoregion (Bailey 1995). The subregions in the study area were the southern, western, and northern Superior uplands, northern Minnesota drift and lake plains, northern highlands, and portions of the eastern and northern Upper Peninsula sections (McNab et al. 2007). The study area consisted of private (53%) and public lands.

The study area was typified by deciduous hardwood, coniferous, mixed deciduous and coniferous, and boreal forests with elevations ranging between 200 and 560 m (Lapinski 2000, Boal et al. 2005, 2006). Wooded wetlands, open wetlands, and swamp habitats were interspersed amidst forests. The western Superior uplands were characterized by forest vegetation of aspen (*Populus* spp.) and birch (*Betula* spp.), maple (*Acer* spp.) and birch, and spruce (*Picea* spp.) and balsam fir (*Abies balsamea*) cover types (McNab et al. 2007). The northern Superior uplands consisted of forest vegetation of mostly aspen-birch, spruce-fir, pine (*Pinus* spp.), and oak (*Quercus* spp.; McNab et al. 2007). Forests in the southern Superior uplands consisted primarily of maple, birch, and aspen species (McNab et al. 2007). The northern Minnesota drift and lake plains region had forest cover consisting of aspen-birch, pine, and spruce-fir (McNab et al. 2007). The northern highlands section was composed of forest cover types of spruce-fir, pine, maple, aspen, and birch (McNab et al. 2007). Forests in the eastern Upper Peninsula region consisted of aspen-birch, maple-birch, pine, and spruce-fir cover types, whereas those in the northern Upper Peninsula landscape were made up of maple-birch and aspen-birch (McNab et al. 2007). Other tree species found in the study area included basswood (*Tilia americana*), black ash (*Fraxinus nigra*), green ash (*F. pennsylvanica*), eastern hemlock (*Tsuga canadensis*), tamarack

(*Larix laricina*), and northern white-cedar (*Thuja occidentalis*).

Development of a Goshawk Landscape-use Model and Stratified Random Sampling Design. We placed a grid of 600-ha squares called Primary Sampling Units (PSUs; Hargis and Woodbridge 2006) over the goshawk breeding range in the WGL bioregion, resulting in a total of 49 146 PSUs. The size of the PSU was defined in the monitoring protocol (Woodbridge and Hargis 2006), and approximated the size of one goshawk territory based on data primarily from western North America. We used location data from 366 goshawk nests obtained from 1979 to 2006 in the WGL and GIS layers to develop a model of goshawk landscape use to assist with designing a stratified random sampling protocol. Using GIS techniques, we centered each nest within a 600-ha square, which corresponded to the PSU size that would later be used for surveying for goshawk presence. Within each square, we randomly placed 120 points that corresponded to the 120 call stations to be visited during surveys (Woodbridge and Hargis 2006). For each of the 366 nest locations, we randomly distributed 20 600-ha squares (i.e., 7320 squares in total), each containing 120 randomly located points, throughout the entire goshawk range to assess habitat that was available, but not known to be used for nesting. We used two different GIS data layers to determine habitat attribute covariates for each 600-ha square. We used the National Land Cover Database (NLCD) land-cover layer with 30-m × 30-m resolution (Homer et al. 2004) to classify the land-cover type of each random point and calculated seven covariates with each defined as the percent of each 600-ha square consisting of different land covers (Appendix, Table A1; Bruggeman et al. 2009). The land-cover layer provided a categorical cover classification for each 30-m × 30-m pixel. We used a U.S. Geological Survey (USGS) forest canopy-cover layer (Huang et al. 2003), which has been assessed and used in other studies (Walton et al. 2008, Sander et al. 2010), to determine the percent canopy cover at each random point and calculated 13 different canopy cover covariates (Appendix, Table A2; Bruggeman et al. 2009). The forest canopy-cover layer provided a value of canopy cover in increments of one percent for each 30-m × 30-m pixel. The forest canopy-cover layer was developed at a spatial resolution of 30 m based on empirical relationships between tree canopy density and Landsat 7 Enhanced Thematic Mapper Plus data, with 1-m digital orthophoto quadrangles used to derive reference tree canopy density data to calibrate relationships between canopy density and Landsat data (Huang et al. 2001, 2003).

We used these data to develop a model predicting goshawk landscape use. We assigned squares consisting of goshawk locations a ''1'' (366 squares) and randomly placed squares a ''0'' (7320 squares) as a binary response variable. We systematically developed 172 logistic regression use/availability models (Hosmer and Lemeshow 2000, Manly et al. 2002) consisting of combinations of the 13 canopy-cover and seven land-cover covariates (Bruggeman et al. 2009). We used PROC LOGISTIC in SAS v9.1 (Allison 1999) to fit models and estimate covariate coefficients. For each model we calculated an Akaike's Information Criterion (AIC) value and an Akaike weight (w), and then ranked and selected top models using ΔAIC values (Burnham and Anderson 2002).

We used the best-supported model to estimate the probability of goshawk landscape use at each of the 366 nest locations and examined a distribution of the probability values to help define ranges for primary, secondary, and non-habitat classifications (Bruggeman et al. 2009). Probability of goshawk landscape use ranged between 0.001 and 0.567 [mean = 0.111; standard deviation (SD) = 0.082; standard error (SE) = 0.004]. We defined primary goshawk habitat to have a probability of use $\geq$0.111, secondary habitat to have a probability between 0.028 and 0.111 (i.e., between the mean – 1 SD and the mean), and non-habitat to have probability $<$0.028. Within each of the 49 146 PSUs (i.e., the WGL bioregion), we randomly placed 120 points and calculated the 20 covariates used in the modeling. We used the best-supported model to predict the probability of goshawk landscape use in each PSU and classified 6860 PSUs as primary habitat, 25 750 as secondary habitat, and 16 536 as non-habitat.

We used GIS layers of federal and state land ownership, and major roads for Michigan, Minnesota, and Wisconsin to determine PSU accessibility. We calculated the nearest Euclidean distance from the centroid of each PSU to a road (paved or Forest Service) and the proportion of each PSU that consisted of project collaborators' lands (e.g., national forests and parks; state forests and parks; tribal organizations). The proportion of each PSU that was composed of project collaborators' lands ranged between 0.0 and 1.0 (mean = 0.533; SE = 0.002), and the distance of each PSU to the nearest road ranged between 0 km and 48 km (mean = 5.00; SE = 0.02). We classified any PSU that had either a proportion of collaborator land ownership $<$0.533 or a distance to road $>$10 km (i.e., mean + 1 SD) as difficult access. We classified easy access PSUs as only those that had both a proportion of collaborator land ownership $\geq$0.533 and a distance to road $\leq$10 km. Within our study area consisting of the seven subregions there were 19 506 PSUs distributed among four strata as follows: (1) 1293 in primary habitat/difficult access; (2) 3564 in primary habitat/easy access; (3) 7047 in secondary habitat/difficult access, and (4) 7602 in secondary habitat/easy access (Fig. 2a). There were an additional 4483 PSUs classified as non-habitat that were removed from the sampling universe. We used an optimal sample-size allocation algorithm to determine the number of PSUs per stratum that could be surveyed given project funding (Hargis and Woodbridge 2006). Our sample of 86 PSUs consisted of seven in the primary habitat/difficult access stratum, 27 in primary habitat/easy access, 22 in secondary habitat/difficult access, and 30 in secondary habitat/easy access (Fig. 2b).

Northern Goshawk Surveys and Habitat Data Collection. Goshawk surveys were conducted under the University of Minnesota Institutional Animal Care and Use Committee, approved protocol number 0806A35181. Between mid-May and mid-August 2008, surveyors systematically surveyed the 86 PSUs in our sample (Fig. 2b) for goshawk presence or absence in accordance with the Northern Goshawk Inventory and Monitoring Technical Guide (Woodbridge and Hargis 2006). Each PSU was surveyed by a field crew of two surveyors apiece with crews consisting of biologists from the U.S. Forest Service, Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Michigan Natural Features Inventory, and University of Minnesota. Each 600-ha PSU contained 120 call stations located on 10 transects spaced 250 m apart (Woodbridge and Hargis 2006). Along each transect were 12 call stations separated by 200 m, with adjacent transect call stations offset by 100 m from north to south to maximize coverage (Woodbridge and Hargis 2006). Trained surveyors used vocal and/or visual responses by goshawks to call broadcasts (Kennedy and Stahlecker 1993) and sightings of recent goshawk activity (e.g., occupied nests, freshly molted feathers, plucking posts and excreta) to determine goshawk presence at and between call stations (Woodbridge and Hargis 2006). Call stations were surveyed until either a goshawk was detected or all 120 stations in the PSU were surveyed (Woodbridge and Hargis 2006). If surveyors detected a goshawk, then the survey for the PSU was complete (Woodbridge and Hargis 2006). Two visits per PSU were scheduled with the first survey conducted between mid-May through late June (i.e., the nestling period) and the second between July and mid-August (i.e., the fledgling period). Using either a Western Rivers Predation (Western Rivers, Lexington, Tennessee, U.S.A.) or FOX PRO FX3 (FOX PRO, Inc., Lewistown, Pennsylvania, U.S.A.) digital caller, surveyors broadcast a goshawk alarm call (Woodbridge and Hargis 2006) at a minimum of 95 dB at each station during the nestling period and alternated between the alarm call and a juvenile food-begging call (Woodbridge and Hargis 2006) at stations during the fledgling period. At each station, surveyors broadcast the call for 10 sec, listened for a response for 30 sec, rotated 120°, and repeated the call/listening sequence. A total of six calling sequences encompassing two complete 360° turns were made at each station. If a detection did not occur during the first visit, then a second visit was required. However, if a detection occurred during the first visit, then a second visit was required only for a subsample of PSUs for the purpose of calculating detection probabilities (Woodbridge and Hargis 2006).

Surveyors recorded habitat data at each call station surveyed for goshawks including the predominant primary and secondary/conifer forest types, and principal structural stage within a 25-m radius around the station. The primary forest type was the dominant species, or multiple species, and was classified as either deciduous or coniferous. A secondary/conifer type was recorded only when a coniferous species, or multiple coniferous species, was present, but was not the dominant type. Deciduous forest types were categorized as: (1) aspen; (2) white birch (*Betula papyrifera*); (3) oak; (4) northern hardwood (combinations of maple, oak, basswood, and ash); (5) northern hardwood with yellow birch (*Betula alleghaniensis*), or (6) swamp hardwood (maple and black ash). Coniferous types were classified as: (1) white pine (*Pinus strobus*); (2) red pine (*Pinus resinosa*); (3) jack pine (*Pinus banksiana*); (4) hemlock; (5) spruce and balsam fir, or (6) swamp conifer [combinations of black spruce (*Picea mariana*), tamarack, or northern white-cedar]. Surveyors also recorded if any of the pine species were part of a pine

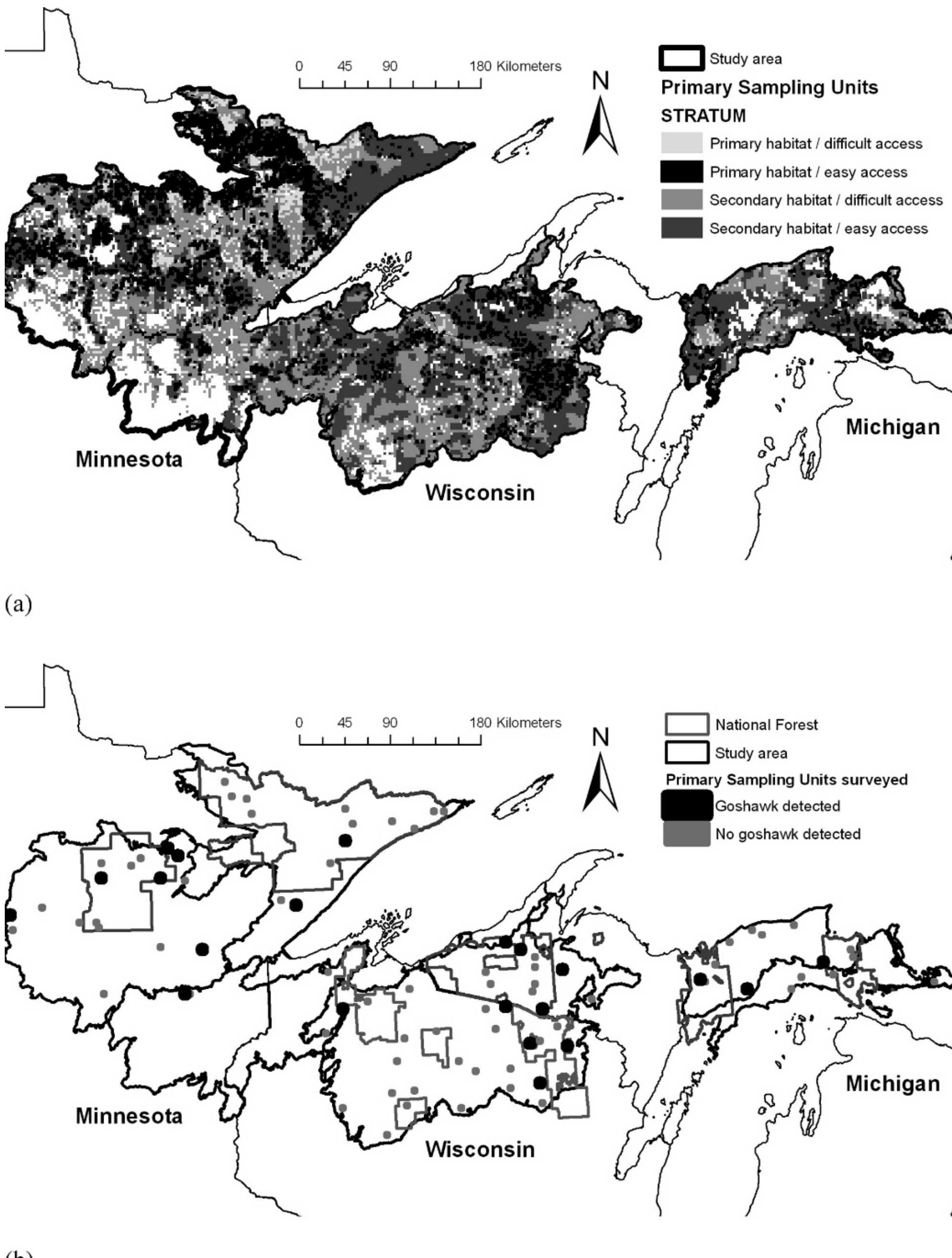


Figure 2. The (a) study area of 19 506 Primary Sampling Units (PSUs) throughout Minnesota, Wisconsin, and Michigan's Upper Peninsula, and (b) 86 PSUs surveyed for Northern Goshawk presence during summer 2008, with those having a goshawk detection and no detection depicted in black and gray, respectively.

plantation. Surveyors classified stations that were surrounded by meadows, water, or developed land as ''non-forested.'' At each station surveyors classified the predominant structural stage into one of five categories: (1) grass, forbs, shrubs, or seedlings; (2) sapling-pole with canopy closure <75% (trees ranging between 2.5 cm and 23 cm diameter at breast height [dbh] size for softwoods; 2.5 cm and 28 cm for hardwoods); (3) sapling-pole with canopy closure >75% (trees ranging between 2.5 cm and 23 cm dbh size for softwoods; 2.5 cm and 28 cm for hardwoods); (4) late-successional with canopy closure <75% (trees >23 cm dbh for softwoods; >28 cm dbh for hardwoods), and (5) late-successional with canopy closure >75% (trees >23 cm dbh for softwoods; >28 cm dbh for hardwoods).

Estimation of Northern Goshawk Occupancy and Detection Probabilities. We used the 2008 survey results to estimate the number of PSUs occupied by goshawks in our study area within the WGL bioregion. We used maximum likelihood techniques to estimate the proportion of PSUs occupied by goshawks (P_i) for each stratum ($1 \le i \le 4$), and the probabilities of missing presence for visit number one (q_1) and visit number two (q_2; Hargis and Woodbridge 2006). We calculated detection probabilities based on presence/absence data recorded for the two visits to each PSU that resulted in one of the following sequences: 00, 01, 10, 1*, or 11, where a ''1'' denotes presence and ''0'' an absence (Hargis and Woodbridge 2006). The 1* sequence applied to PSUs surveyed in visit number one and where a goshawk was detected, but not surveyed again (Hargis and Woodbridge 2006). We estimated standard errors for each P_i using bootstrap methods (Efron and Tibshirani 1993). The sample size for each stratum was the number of PSUs surveyed in each stratum (n_i) and we selected 1000 bootstrap samples of size n_i for each stratum using random sampling with replacement. We calculated the mean proportion of PSUs occupied by goshawks from the sample and the associated standard error from the bootstrap sample (SE_i). We then determined the sample variance of the mean proportion of PSUs occupied by goshawks for each stratum as $\sigma_i^2 = SE_i^2 * n_i$. We used P_i, determined from maximum likelihood estimates, and σ_i^2, determined from bootstrapping, in stratified random sampling equations (Thompson 2002) to estimate the total number and proportion of PSUs in our study area occupied by goshawks and the associated variance for each. Likewise, we estimated standard errors for q_1 and q_2 using bootstrap methods (Efron and Tibshirani 1993). The sample size for q_1 was 17 because 17 PSUs had detection sequences of 01 or 11 whereas the sample size for q_2 was 12 because 12 PSUs had sequences of 10 or 11. We selected 1000 bootstrap samples of size 17 for q_1 and 12 for q_2 using random sampling with replacement. We calculated the mean detection probabilities from each sample and the associated standard error.

Power Analyses. We conducted power analyses (Cohen 1992) in R (R Development Core Team 2008) to examine the ability to detect a change (i.e., increase or decrease) or decline in goshawk occupancy in our study area with the next survey. Using the coefficient of variation (CV) of occupancy determined from maximum likelihood and bootstrap standard error estimates, we examined how varying the percent change in occupancy influenced the power to detect a change or decline in occupancy at a significance level, α, of 0.05.

Using the CV of occupancy determined from maximum likelihood and bootstrap standard error estimates, we also conducted prospective power analyses using TRENDS software (Gerrodette 1993) to determine the number of surveys required to determine a significant population trend (Gerrodette 1987) at varying rates of change (r) at a power of 0.8, $\alpha = 0.05$, and assuming an exponential population model. Woodbridge and Hargis (2006) suggested repeating bioregional surveys annually and analyzing for trends every five years and thus, we evaluated r for 5-yr intervals. We evaluated the number of surveys required to determine a significant trend at 5-yr rates of change of −0.1, −0.2, −0.3, −0.4, −0.5, 0.1, 0.2, 0.3, 0.4, and 0.5.

RESULTS

Modeling Goshawk Landscape Use. There were five models with $\Delta AIC < 2$ with the best-supported model having $w = 0.191$ and relative likelihoods of 1.1 and 1.8 compared to the second- and third-best models, respectively (Bruggeman et al. 2009). The top-approximating model contained the following significant land-cover type covariates each having 95% confidence intervals not spanning zero: percentage of deciduous forest (estimate = 0.023, SE = 0.010), percentage of coniferous forest (estimate = 0.369, SE = 0.065), and percentage of mixed deciduous/coniferous forest (estimate = 0.039, SE = 0.012). The top model contained the following significant forest canopy cover covariates with 95% confidence intervals that did not overlap zero: forest canopy cover of 50–59% (estimate = 0.091, SE = 0.035), forest canopy cover of 70–79% (estimate = 0.081, SE = 0.024), forest canopy cover of 80–89% (estimate = 0.089, SE = 0.029), and forest canopy cover of 90–100% (estimate = 0.076, SE = 0.037). The top model also contained an interaction between the percentage of coniferous forest land cover and the maximum percentage of canopy cover (estimate = −0.004; SE = 0.001).

2008 Survey Results and Estimation of Goshawk Occupancy. During first survey visits lasting from mid-May through June 2008, surveyors detected goshawk presence in 13 of 86 PSUs (15.1%) with detections classified as: four occupied nests, one vocal response, four sightings, three combined vocal responses and sightings, and one sign of goshawk presence consisting of a plucking post. During second surveys, conducted between July and mid-August 2008, surveyors detected goshawk presence in 17 of 85 PSUs (20%) with detections categorized as: four occupied nests, two vocal responses, three sightings, seven combined vocal responses and sightings, and one sign of goshawk presence consisting of a plucking post, excreta, and prey remains. One PSU surveyed in the first visit and determined to have goshawk presence was not surveyed again owing to time constraints. We detected goshawks on 30 occasions between the two visits to PSUs in 21 different PSUs (Fig. 2b). Nine PSUs had goshawk presence during both visits (Fig. 2b). Goshawk response rates varied between habitat strata with goshawk presence detected in six of 34 (17.6%) and seven of 52 (13.5%) of primary and secondary habitat PSUs, respectively, during first survey visits. In the second survey visits, there were 10 of 34 (29.4%) and seven of 51 (13.7%) of primary and secondary habitat PSUs, respectively, with goshawk presence.

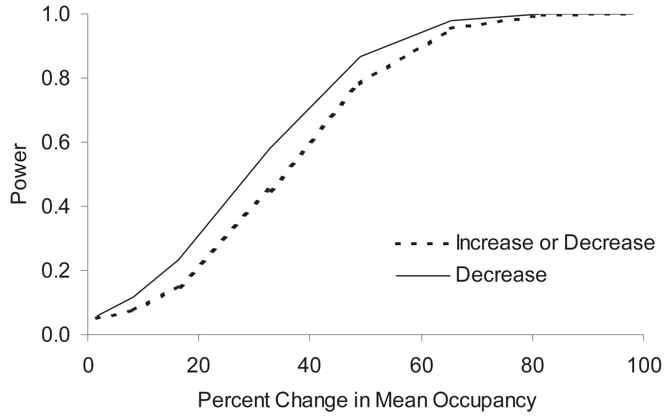
We estimated the proportion of PSUs occupied by goshawks as 0.266 ± 0.047 (SE), which corresponded to a total of 5184 ± 914 PSUs (95% confidence interval [CI]: 3365, 7004) occupied by goshawks in our study area in 2008. The study area contained 19 506 PSUs classified as potential goshawk habitat and, therefore, we estimated goshawks occupied 27% of the area. We estimated the proportion of PSUs occupied by goshawks for each stratum (P_i) as 0.483 ± 0.190, 0.292 ± 0.083, 0.256 ± 0.088, and 0.225 ± 0.072 for the primary habitat/difficult access, primary habitat/easy access, secondary habitat/difficult access, secondary habitat/easy access strata, respectively. Goshawk detection probabilities were q_1 = 0.549 ± 0.118 for the first visit to PSUs and q_2 = 0.750 ± 0.126 for the second visit.

Power Analyses. The CV of goshawk occupancy based on maximum likelihood occupancy (0.266) and bootstrap standard deviation (0.434) estimates was 1.63. The smallest detectable change and decrease in estimated occupancy that could be determined with the next survey at a power of 0.8 and α = 0.05 was 50.0% and 44.2%, respectively (Fig. 3a). The minimum number of surveys at 5-yr intervals required to detect a significant decreasing trend in occupancy ranged from 10 for $r = -0.50$ to 46 for $r = -0.04$, with r representing the 5-yr rate of change (Fig. 3b). The minimum number of surveys at 5-yr intervals required to detect a significant increasing trend in occupancy ranged from eight for $r = 0.50$ to 36 for $r = 0.04$ (Fig. 3b). Combinations of the CV and $-0.05 < r < 0.05$ resulted in an error message using TRENDS software (Gerrodette 1993), indicating an inability to detect small rates of change given the variability in the data.

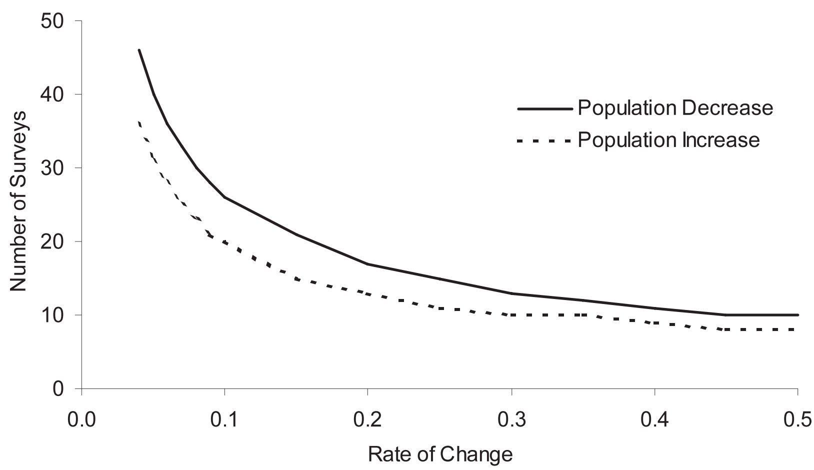
Goshawk Habitat Use. The 30 goshawk detections in sampled PSUs occurred at 23 different call stations having forest structural stages ranging between categories two and five with 52% of locations in stage three forest, 22% in stage five, 13% in stage four, and 13% in stage two. Goshawk detections occurred at call stations consisting of 12 different primary forest types, although 30% of locations were in northern hardwood forest and 13% were in aspen/white birch forest. Aspen, northern hardwood with yellow birch, and swamp conifer forest types each had two goshawk detections, whereas hemlock/white pine, hemlock/northern hardwood, oak/aspen/white birch, red pine, spruce/fir, swamp hardwood, and white birch forest types each had one. Twelve detection locations also had secondary/conifer forest types, of which 33% were in spruce/fir, 25% in spruce/fir/pine, and 17% in white pine.

DISCUSSION

We estimated that 5184 PSUs were occupied by goshawks in our study area within the WGL bioregion in 2008. This provides a baseline estimate of goshawk occupancy and suggests goshawks were widely, but sparsely, distributed throughout the bioregion. The WGL bioregion includes the southern periphery of the goshawk breeding range that extends north into Canada (Squires and Reynolds 1997). Caughley et al. (1988) suggested that many species occur at higher densities at the core of their



(a)



(b)

Figure 3. (a) The relationship between the power to detect a change at $\alpha = 0.05$ and the smallest detectable percent change (i.e., increase or decrease) or decrease in mean occupancy with the next bioregional survey, and (b) number of surveys conducted at 5-yr intervals required to detect a significant trend in the proportion of Primary Sampling Units occupied by goshawks at 5-yr rates of change (r) ranging between -0.5 and 0.5. Combinations of the coefficient of variation and $-0.05 < r < 0.05$ resulted in an error message using TRENDS software (Gerrodette 1993).

range; therefore, our occupancy estimates may represent relatively lower densities of breeding goshawks than may occur elsewhere in North America.

Habitat data recorded at calling stations during 2008 indicated a strong relationship between goshawk occupancy and high amounts of canopy cover. A total of 74% of detections occurred at call stations having forest succession categories with canopy closure >75%. Furthermore, the best-supported model of goshawk landscape use included four significant canopy-cover covariates, suggesting the importance of greater percentages of forest with high canopy cover (>50%) on goshawk use. These results reinforce the need for maintaining contiguous forested areas with high amounts of canopy cover to provide adequate resources for goshawks. Key prey species, such as red squirrels (*Tamiasciurus hudsonicus*), Ruffed Grouse (*Bonasa umbellus*), eastern chipmunks (*Tamias striatus*), and snowshoe hares (*Lepus americanus*: Smithers et al. 2005, Woodford et al. 2008), are found primarily in forested habitats, especially those with understory growth and woody debris (Litvaitis et al. 1985, Bayne and Hobson 2000). Wiens et al. (2006a) documented the importance of prey availability on survival of juvenile goshawks in northern Arizona and suggested forests be managed to support abundant prey populations while simultaneously providing forest structure suitable for goshawk foraging (Beier and Drennan 1997). Previous studies of goshawk nesting and foraging habitats in the WGL bioregion also have indicated the importance of mature forest stands with high amounts of canopy cover (Rosenfield et al. 1998, Boal et al. 2005).

Our 2008 surveys documented use of a variety of forest types by goshawks with most detections at call stations surrounded by northern hardwood and aspen/white birch forests. Goshawk detection locations in coniferous habitat types were primarily in spruce, fir, and pine forests. Additionally, the top model of goshawk landscape use included significant forest-type covariates with the percentages of deciduous, coniferous, and mixed deciduous/coniferous forest all having coefficients with 95% confidence intervals not spanning zero. The use of a variety of forest types by goshawks in our study agrees with previous work in the WGL bioregion and western North America (Boal et al. 2006). In Minnesota, foraging male goshawks used both mature and old upland deciduous and coniferous forest stands more frequently than expected based on availability (Boal et al. 2005). Goshawk nests in Wisconsin have been found in a wide variety of tree species with most occurring in northern hardwood forest types (Woodford et al. 2008). Also, goshawks selected hardwood and mixed hardwood/conifer forests more than other cover types in Michigan (Lapinski 2000). Our results, along with the existing literature on goshawk habitat use, suggest tree species has little influence on use of forests by goshawks and that canopy cover is a more influential factor. However, our results cannot be used to determine whether goshawks selected for certain types because we did not have complete data on availability of forest types.

Our estimates of detection probabilities were lower for the first survey visit (0.549; 95% CI: 0.292, 0.807) than for the second (0.750; 95% CI: 0.485, 1.000), but confidence intervals overlapped. Surveyors detected goshawk presence in 17.6% of PSUs during the first survey visit and 29.4% of PSUs for the second survey visit in primary habitat strata. Factors that may contribute to lower detectability of goshawks during the nestling period, specifically during May, include variability in spring weather that may affect the timing of nesting and incubation, and differences among individual goshawks with respect to parental care (Dewey and Kennedy 2001). Roberson et al. (2005) documented detection probabilities of only 28% during the nestling phase compared to 68% in the fledgling phase for goshawk surveys in Minnesota. Nesting raptors in general are often easier to locate later in the nesting season because of adult defenses of the young and nest, and vocalizations from young (Steenhof and Newton 2007).

The proportion of PSUs with goshawk occupancy in primary habitat PSUs with difficult and easy access was 0.483 (95% CI: 0.033, 0.933) and 0.292 (95% CI: 0.121, 0.463), respectively, and this difference may be the result of multiple factors. First, the sample size for primary habitat/difficult access was only seven PSUs compared to 27 for the primary habitat/easy access stratum because the number of PSUs in the sampling universe was lower for the primary habitat/difficult access stratum. Results from the small sample may not represent the true population, and the difference between probabilities may be a statistical artifact. Second, in contrast to private lands having access classified as difficult, public lands with easy access in the study area, such as national and state forests and state parks, are likely to be managed for multiple uses, including recreation and resource management that may decrease the probability of goshawk use. Third, areas farther from roads are less likely to receive human use, and if goshawks have low tolerance for human activity near nests or in breeding areas, more remote areas may exhibit a higher likelihood of goshawk use. We were unable to assess what factors influenced differences in goshawk occupancy between PSUs with difficult and easy access, but this warrants further examination in conjunction with future monitoring efforts. Occupancy modeling has advanced since the Hargis and Woodbridge (2006) protocol and it may be worthwhile to estimate detection probabilities for each of the four strata to provide additional insights.

Our results illustrated the value of a well-defined sampling design for conducting surveys. Of 21 goshawk detections from different PSUs, 11 were in a secondary habitat strata with at least several of these detections in what would have been considered to be low-quality habitat prior to our 2008 surveys. In contrast, the 366 goshawk nest locations used to develop the model of landscape use were obtained by assorted methods, including sightings near roads or searching perceived high-quality habitat. Previous work by Daw et al. (1998) found no differences in forest structural properties between nest sites found opportunistically compared to those found during systematic surveys. However, they cautioned that reliable density estimates, repeatability of methods, and comparisons among years and studies could only be attained through systematic methods (Daw et al. 1998). Whether potential bias existed in the historical locations used to develop our predictive model is difficult to determine.

Power analyses indicated that a 50% change in goshawk occupancy could be detected at a power of 0.8 with a second bioregional survey. The estimate of occupancy for 2008 was 0.266 ± 0.047 and, therefore, an increase or decrease as small as 0.133 may be determined at a power of 0.8. Power analyses indicated at least 10 surveys for a 5-yr rate of change of -0.5 must be conducted if surveys are done every five years to detect a significant decreasing trend in the proportion of PSUs occupied by goshawks. At least eight surveys for a 5-yr rate of change of 0.5 must be conducted to detect a significant increasing trend in occupancy with time. Of course, trade-offs exist between conducting surveys annually compared to every five years. Annual surveys are resource-intensive and require continuous funding and partnership commitments, but they also provide the means of detecting smaller changes in occupancy over comparable timeframes because of the increased sample size of surveys. Annual surveys also provide a better opportunity to examine effects of interannual climate variability on goshawk population trends and to understand how much variation in occupancy occurs among years. Surveys conducted every five years are less resource-intensive and allow project collaborators to commit funds to other priority projects during years without surveys.

Our results provide the first estimate of goshawk occupancy for our study area in the WGL bioregion based on the Hargis and Woodbridge (2006) monitoring protocol. Given its potential for providing insights into both management and ecological issues, the monitoring is likely to be implemented in other bioregions throughout the country over the next several years. However, based on our findings and the amount of resources committed to the project, we recommend the surveys best be used to determine one-time population status and offer insights into locations of goshawks for future intensive research by federal and state agencies as opposed to determining population trend with multiple surveys over time. Based on surveying 86 PSUs in the WGL bioregion, our power analyses indicated that only a 50% change in the occupancy of PSUs could be detected with the next bioregional survey. Project partners provided >\$200 000 plus additional in-kind effort to complete the 2008 surveys; attempting to determine a trend with that kind of commitment every five years is not likely to be worthwhile no matter the economic climate.

We offer the following additional suggestions for instituting bioregional surveys and monitoring based on our experience and findings. First, surveys should encompass all land ownership types and not just U.S. Forest Service lands or other public lands. Inference about a regional population can only be obtained using a sampling design that includes surveying both public and private lands if they include potential goshawk habitat. Although this approach requires cooperation among project collaborators and private landowners, it offers valuable insights into goshawk-habitat associations not possible with monitoring only public lands. Second, we recommend using a stratified sampling design, as opposed to random sampling of PSUs, to increase the precision of the occupancy estimate while operating with a fixed budget to ensure surveying both primary and secondary habitats (Woodbridge and Hargis 2006). Development of a stratified sampling design requires some knowledge of goshawk landscape use, which can be obtained using a combination of existing location data and GIS layers spanning the entire bioregion. GIS layers of habitat attributes for national and state forests may provide detail and high resolution, but these layers may not be available across the entire bioregion. We were constrained to use land and forest canopy cover data with 30-m resolution that provided coverage across all types of land ownership because the WGL bioregion consists of a combination of public and private lands. Although some misclassification of primary and secondary habitat PSUs undoubtedly occurred, use of a random sampling design with no knowledge of prior goshawk landscape use would have been less efficient and resulted in an occupancy estimate with higher variance.

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LITERATURE CITED

ALLISON, P.D. 1999. Logistic regression using the SAS system: theory and application. SAS Institute, Inc., Cary, NC U.S.A.

ANDERSEN, D.E., S. DESTEFANO, M.I. GOLDSTEIN, K. TITUS, 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* 39:192–209.

BAILEY, R.G. 1995. Description of the ecoregions of the United States. Miscellaneous Publication No. 1391, Second Ed. revised. USDA, Washington, DC U.S.A.

BAYNE, E. AND K. HOBSON. 2000. Relative use of contiguous and fragmented forest by red squirrels (*Tamiasciurus hudsonicus*). *Canadian Journal of Zoology* 78:359–365.

BEIER, P. AND J.E. DRENNAN. 1997. Forest structure and prey abundance in foraging areas of Northern Goshawks. *Ecological Applications* 7:564–571.

BOAL, C.W., D.E. ANDERSEN, AND P.L. KENNEDY. 2005. Foraging and nesting habitat of breeding male Northern Goshawks in the Laurentian Mixed Forest Province, Minnesota. *Journal of Wildlife Management* 69:1516–1527.

———, ———, ———, AND A.M. ROBERSON. 2006. Northern Goshawk ecology in the western Great Lakes region. *Studies in Avian Biology* 31:126–134.

BRUGGEMAN, J.E., D.E. ANDERSEN, AND J.E. WOODFORD. 2009. Bioregional monitoring for Northern Goshawks in the western Great Lakes. Final Report. http://wiatri.net/inventory/Raptors/goshawks/reports.htm (last accessed 1 February 2011).

BURNHAM, K.P. AND D.R. ANDERSON. 2002. Model selection and multimodel inference: a practical information-theoretic approach, Second Ed. Springer-Verlag, New York, NY U.S.A.

CAUGHLEY, G., D. GRICE, R. BARKER, AND B. BROWN. 1988. The edge of the range. *Journal of Animal Ecology* 57:771–785.

COHEN, J. 1992. A power primer. *Psychology Bulletin* 112:155–159.

DAW, S.K., S. DESTEFANO, AND R.J. STEIDL. 1998. Does survey method bias the description of Northern Goshawk nest-site structure? *Journal of Wildlife Management* 62:1379–1384.

DEWEY, S.R. AND P.L. KENNEDY. 2001. Effects of supplemental food on parental-care strategies and juvenile survival of Northern Goshawks. *Auk* 118:352–365.

DOYLE, F.I. AND J.M.N. SMITH. 2001. Raptors and scavengers. Pages 378–404 *in* C.J. Krebs, S. Boutin, and R. Boonstra [EDS.], Ecosystem dynamics of the boreal forest. Oxford University Press, New York, NY U.S.A.

EFRON, B. AND R.J. TIBSHIRANI. 1993. An introduction to the bootstrap. Chapman and Hall, New York, NY U.S.A.

FAIRHURST, G.D. AND M.J. BECHARD. 2005. Relationships between winter and spring weather and Northern Goshawk (*Accipiter gentilis*) reproduction in northern Nevada. *Journal of Raptor Research* 39:229–236.

GERRODETTE, T. 1987. A power analysis for detecting trends. *Ecology* 68:1364–1372.

———. 1993. TRENDS: software for a power analysis of linear regression. *Wildlife Society Bulletin* 21:515–516.

HARGIS, C.D. AND B. WOODBRIDGE. 2006. A design for monitoring Northern Goshawks (*Accipiter gentilis*) at the bioregional scale. *Studies in Avian Biology* 31:274–287.

HOMER, C., C. HUANG, L. YANG, B. WYLIE, AND M. COAN. 2004. Development of a 2001 National Land Cover Database for the United States. *Photogrammetric Engineering and Remote Sensing* 70:829–840.

HOSMER, D.W. AND S. LEMESHOW. 2000. Applied logistic regression. John Wiley and Sons, Inc., New York, NY U.S.A.

HUANG, C., C. HOMER, AND L. YANG. 2003. Regional forest land cover characterization using Landsat type data. Pages 389–410 *in* M. Wulder and S. Franklin [EDS.], Remote sensing of forest environments: concepts and case studies. Kluwer Academic Publishers, Norwell, MA U.S.A.

———, L. YANG, B. WYLIE, AND C. HOMER. 2001. A strategy for estimating tree canopy density using Landsat 7 ETM+ and high resolution images over large areas. Proceedings of the Third International Conference on Geospatial Information in Agriculture and Forestry, Denver, CO U.S.A.

KENNEDY, P.L. AND D.W. STAHLECKER. 1993. Responsiveness of nesting Northern Goshawks to taped broadcasts of 3 conspecific calls. *Journal of Wildlife Management* 57:249–257.

LAPINSKI, N.W. 2000. Habitat use and productivity of the Northern Goshawk in the Upper Peninsula of Michigan. M.S. thesis, Northern Michigan Univ., Marquette, MI U.S.A.

LITVAITIS, J.A., J.A. SHERBURNE, AND J.A. BISSONETTE. 1985. Influence of understory characteristics on snowshoe hare habitat use and density. *Journal of Wildlife Management* 49:866–873.

MANLY, B.F., L.L. MCDONALD, D.L. THOMAS, T.L. MCDONALD, AND W.P. ERICKSON. 2002. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, New York, NY U.S.A.

MCNAB, W.H., D.T. CLELAND, J.A. FREEOUF, J.E. KEYS, JR., G.J. NOWACKI, AND C.A. CARPENTER [COMPILERS]. 2007. Description of ecological subregions: sections of the conterminous United States. U.S. Forest Service Gen. Tech. Rep. WO-76B, Washington, DC U.S.A.

POLLOCK, K.H., J.D. NICHOLS, T.R. SIMONS, G.L. FARNSWORTH, L.L. BAILEY, AND J.R. SAUER. 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. *Environmetrics* 13:105–119.

R DEVELOPMENT CORE TEAM. 2008. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org (last accessed 18 July 2010).

REYNOLDS, R.T., R.T. GRAHAM, AND D.A. BOYCE, JR. 2008. Northern Goshawk habitat: an intersection of science, management, and conservation. *Journal of Wildlife Management* 72:1047–1055.

———, J.D. WIENS, S.M. JOY, AND S.R. SALAFSKY. 2005. Sampling considerations for demographic and habitat studies of Northern Goshawks. *Journal of Raptor Research* 39:274–285.

ROBERSON, A.M., D.E. ANDERSEN, AND P.L. KENNEDY. 2005. Do breeding phase and detection distance influence the effective area surveyed for Northern Goshawks? *Journal of Wildlife Management* 69:1240–1250.

ROSENFIELD, R.N., T.C.L. DOOLITTLE, D.R. TREXEL, AND J. BIELEFELDT. 1998. Breeding distribution and nest-site habitat of Northern Goshawks in Wisconsin. *Journal of Raptor Research* 32:189–194.

SALAFSKY, S.R., R.T. REYNOLDS, AND B.R. NOON. 2005. Patterns of temporal variation in goshawk reproduction and prey resources. *Journal of Raptor Research* 39:237–246.

SANDER, H., S. POLASKY, AND R.G. HAIGHT. 2010. The value of urban tree cover: a hedonic property price model in Ramsey and Dakota counties, Minnesota, USA. *Ecological Economics* 69:1646–1656.

SIDERS, M.S. AND P.L. KENNEDY. 1994. Nesting habitat of accipiter hawks: is body size a consistent predictor of nest habitat characteristics? *Studies in Avian Biology* 16:92–96.

SMITHERS, B.L., C.W. BOAL, AND D.E. ANDERSEN. 2005. Northern Goshawk diet in Minnesota: an analysis using video recording systems. *Journal of Raptor Research* 39:264–273.

SQUIRES, J.R. AND P.L. KENNEDY. 2006. Northern Goshawk ecology: an assessment of current knowledge and information needs for conservation and management. *Studies in Avian Biology* 31:8–62.

——— AND R.T. REYNOLDS. 1997. Northern Goshawk (*Accipiter gentilis*). *In* A. Poole and F. Gill [EDS.], The birds of North America, No. 298. The Academy of Natural Sciences, Philadelphia, PA U.S.A. and The American Ornithologists' Union, Washington, DC U.S.A.

——— AND L.F. RUGGIERO. 1996. Nest-site preference of Northern Goshawks in southcentral Wyoming. *Journal of Wildlife Management* 60:170–177.

STEENHOF, K. AND I. NEWTON. 2007. Assessing nesting success and productivity. Pages 181–192 *in* D.M. Bird and K.L. Bildstein [EDS.], Raptor research and management techniques, Hancock House Publishers, Blaine, WA U.S.A.

THOMPSON, S.K. 2002. *Sampling.* John Wiley and Sons, Inc., New York, NY U.S.A.

WALTON, J.T., D.J. NOWACK, AND E.J. GREENFIELD. 2008. Assessing urban forest canopy cover using airborne or satellite imagery. *Arboriculture and Urban Forestry* 34:334–340.

WIENS, J.D., B.R. NOON, AND R.T. REYNOLDS. 2006a. Post-fledgling survival of Northern Goshawks: the importance of prey abundance, weather, and dispersal. *Ecological Applications* 16:406–418.

———, R.T. REYNOLDS, AND B.R. NOON. 2006b. Juvenile movement and natal dispersal of Northern Goshawks in Arizona. *Condor* 108:253–269.

WOODBRIDGE, B. AND C.D. HARGIS. 2006. Northern Goshawk inventory and monitoring technical guide. U.S. Forest Service Gen. Tech. Rep. WO-71, Washington, DC U.S.A.

WOODFORD, J.E., C.A. ELORANTA, AND K.D. CRAIG. 2008. Nest monitoring and prey of Northern Goshawks in Wisconsin. *Passenger Pigeon* 70:171–179.

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APPENDIX

Table A1. The seven land-cover covariates used in the analysis to develop a model predicting Northern Goshawk landscape use in the western Great Lakes bioregion. Covariates were calculated based on 120 randomly placed points in 600 ha squares surrounding "used" goshawk locations from 1979–2006 and randomly placed "available" locations.

COVARIATE
Percentage of aquatic habitat in each 600 ha square
Percentage of deciduous forest habitat in each 600 ha square
Percentage of coniferous forest habitat in each 600 ha square
Percentage of mixed deciduous/evergreen forest in each 600 ha square
Percentage of shrub and grassland habitat in each 600 ha square
Percentage of agricultural, pasture, or crop habitat in each 600 ha square
Percentage of wetland/herbaceous wetland habitat in each 600 ha square

Table A2. The 13 forest canopy-cover covariates used in the analysis to develop a model predicting Northern Goshawk landscape use in the western Great Lakes bioregion. Covariates were calculated based on 120 randomly placed points in 600 ha squares surrounding ''used'' goshawk locations from 1979–2006 and randomly placed ''available'' locations.

COVARIATE
Average percentage of forest canopy cover in each 600 ha square
Maximum percentage of forest canopy cover in each 600 ha square
Standard deviation of forest canopy cover in each 600 ha square
Percentage of the 600 ha square with canopy cover between 0–9%
Percentage of the 600 ha square with canopy cover between 10–19%
Percentage of the 600 ha square with canopy cover between 20–29%
Percentage of the 600 ha square with canopy cover between 30–39%
Percentage of the 600 ha square with canopy cover between 40–49%
Percentage of the 600 ha square with canopy cover between 50–59%
Percentage of the 600 ha square with canopy cover between 60–69%
Percentage of the 600 ha square with canopy cover between 70–79%
Percentage of the 600 ha square with canopy cover between 80–89%
Percentage of the 600 ha square with canopy cover between 90–100%