

ESTIMATING SITE OCCUPANCY AND DETECTION PROBABILITIES FOR COOPER'S AND SHARP-SHINNED HAWKS IN THE SOUTHERN SIERRA NEVADA

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ABSTRACT.—Long-term monitoring programs that can detect a population change over time can be useful for managers interested in assessing population trends in response to forest management activities for a particular species. Such long-term monitoring programs have been designed for the Northern Goshawk (*Accipiter gentilis*), but not for the more elusive Sharp-shinned (*A. striatus*) and Cooper's hawks (*A. cooperii*). The objectives of this study were to (1) determine if it was possible to survey for these two *Accipiters* at the same time successfully using a new survey technique, and (2) estimate occupancy rate and detection probabilities for both species. We used broadcast surveys (BSM) to determine presence/absence for nesting Sharp-shinned and Cooper's hawks at Mountain Home Demonstration State Forest located in the southern Sierra Nevada mountain range in California. We surveyed 34 sampling units that were defined as the average home-range size (1000 m²) of the smallest target species, the Sharp-shinned Hawk. The sampling units were surveyed twice in 2003 and 3–4 times in 2004 during the breeding season. We used program PRESENCE to estimate detection probabilities and model occupancy rates for Sharp-shinned and Cooper's hawks. Our results indicated that the BSM using both *Accipiter* vocalizations in sequence was valuable for surveying both Sharp-shinned and Cooper's hawks. Proportions of the study area occupied for Sharp-shinned and Cooper's hawks were 0.25 (SE = 0.079), and 0.40 (SE = 0.098), respectively. The probabilities of detecting Cooper's and Sharp-shinned hawks at any given site were 0.56 (SE = 0.098) and 0.47 (SE = 0.086), respectively. There were no published occupancy estimates or detection probabilities in the literature to directly compare to our study. Because these species are elusive and difficult to survey, it is imperative future studies that address occupancy estimation for Sharp-shinned and Cooper's hawk incorporate detection probabilities into their model. Incorporating other variables into an occupancy model, such as habitat type, timber harvest, forest health, and/or climatic variables will also improve occupancy estimates.

KEY WORDS: *Sharp-shinned Hawk*; *Accipiter striatus*; *Cooper's Hawk*; *Accipiter cooperii*; *detection probability*; *long-term monitoring*; *site occupancy*; *survey techniques*.

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ESTIMA DE LA OCUPACIÓN Y DE LAS PROBABILIDADES DE DETECCIÓN DE *ACCIPITER COOPERII* Y *ACCIPITER STRIATUS* EN EL SUR DE SIERRA NEVADA

RESUMEN.—Los programas de seguimiento a largo plazo que pueden detectar un cambio poblacional a lo largo del tiempo pueden ser útiles para los gestores interesados en la evaluación de tendencias poblacionales en respuesta a actividades de gestión forestal para una especie en particular. Estos programas de seguimiento a largo plazo han sido diseñados para *Accipiter gentilis*, pero no para especies más elusivas tales como *Accipiter striatus* y *Accipiter cooperii*. Los objetivos de este estudio fueron (1) determinar si fue posible censar simultáneamente con éxito a estos dos accipítridos utilizando una nueva técnica de censo y (2) estimar la tasa de ocupación y la probabilidad de detección para ambas especies. Utilizamos censos de emisión de reclamos (CER) para determinar la presencia/ausencia de individuos nidificantes de *A. striatus* y *A. cooperii* en el Bosque Estatal Mountain Home Demonstration ubicado en el sur de la cadena montañosa de Sierra Nevada en California. Censamos 34 unidades de muestreo, que fueron definidas en base al tamaño promedio del área de campeo (1000 m²) de la especie objeto de estudio más pequeña, *A. striatus*. Las unidades de muestreo fueron censadas dos veces en 2003 y 3-4 veces en 2004 durante la época reproductora. Utilizamos el programa estadístico PRESENCE para estimar las probabilidades de detección y para modelizar las tasas de ocupación de *A. striatus* y *A. cooperii*. Nuestros resultados indican que la CER, utilizando vocalizaciones secuenciales de las dos especies de accipítridos, fue una metodología valiosa para censar ambas especies. Las proporciones del área de estudio ocupadas por *A. striatus* y *A. cooperii* fueron de 0.25 (EE = 0.079) y 0.40 (EE = 0.098), respectivamente. La probabilidad de detección de *A. cooperii* y *A. striatus* en cualquier sitio fue de 0.56 (EE = 0.098) y 0.47 (SE = 0.086), respectivamente. No encontramos estimas de ocupación o de probabilidades de detección publicadas en la literatura para compararlas directamente con nuestro estudio. Debido a que estas especies son elusivas y difíciles de estudiar, es imperativo que los estudios futuros que aborden la estima de ocupación para ambas especies incorporen la probabilidad de detección en sus modelos. La incorporación de otras variables en un modelo de ocupación, tales como el tipo de hábitat, la extracción de madera, la salud del bosque y/o las variables climáticas también van a mejorar las estimas de ocupación.

[Traducción del equipo editorial]

The distribution of *Accipiter* hawks in the southern Sierra Nevada Mountain Range in California (hereafter Sierra Nevada) is not well understood, especially that of the two smaller *Accipiters* that occur in California, the Sharp-shinned (*A. striatus*) and Cooper's hawk (*A. cooperii*). Zeiner et al. (1988) stated that the Sharp-shinned Hawk no longer breeds in the extreme southern distribution of its range in the Sierra Nevada. Both species were listed as a California Species of Special Concern in 1978 by the California Department of Fish and Wildlife, primarily because of concerns regarding habitat loss (Remsen 1978, Fletcher 2003). However, these two species were removed recently from the Species of Special Concern list (Shuford and Gardali 2008). The authors justified this because Cooper's Hawk populations in California had increased and Sharp-shinned Hawks had neither increased nor decreased. However, both species are on the list of taxa to "watch."

Both Sharp-shinned and Cooper's hawks are elusive and usually require an intensive survey effort to detect individuals and locate nests (Rosenfield and Bielefeldt 1993, Bildstein and Meyer 2000). However, survey protocols have only been established

for the Northern Goshawk (*A. gentilis*), the largest of the three species in the *Accipiter* genus. The protocol for the Northern Goshawk is highly effective for locating territories and nests (Kennedy and Stahlecker 1993, Joy et al. 1994). Studies show that using broadcast tape-recorded calls of conspecifics is a useful technique to detect Sharp-shinned and Cooper's hawks (Rosenfield et al. 1985, 1988, Mosher et al. 1990). These studies, however, did not quantify the effectiveness of their surveys in detecting occupied territories or for simultaneous surveys for the two species.

Other studies that focus primarily on Northern Goshawks emphasized a need for more information on survey techniques (Joy et al. 1994, Roberson et al. 2005, Beck et al. 2011). In the last decade, occupancy modeling has become very popular and advancements have been made in this area of research. In 2006, a Northern Goshawk Inventory and Monitoring Technical Guide was published by the United States Department of Agriculture Forest Service that outlined standardized protocols for goshawk monitoring (Woodbridge and Hargis 2006). There is no standardized protocol for Sharp-shinned or Cooper's hawks. Accounting for uncertain detection

probability in estimates of abundance or occupancy has the potential to improve a manager's ability to monitor species' response to land management activities, including prescribed fire and timber harvest (Woodbridge and Hargis 2006). The objectives of this study were to (1) determine if it was possible to survey for these two *Accipiters* at the same time successfully using a new survey technique, and (2) estimate site occupancy and detection probabilities for Cooper's and Sharp-shinned Hawks using MacKenzie's (2002) occupancy modeling approach, which is ideal for elusive species like Sharp-shinned and Cooper's hawks.

STUDY AREA AND METHODS

Our 3398 ha study area was located in the southern Sierra Nevada on federal, state, and private lands approximately 45 km northeast of the town of Porterville in Tulare County, California (36°3.32'N, 118°40.8'W). The study area was centered on Mountain Home Demonstration State Forest (MHDSF), which is managed by California Department of Forestry and Fire Protection. MHDSF and the surrounding area consists of Sierran mixed conifer forest containing over 5000 individual old-growth giant sequoia (*Sequoiadendron giganteum*) trees (Dulitz 1994). Vegetation types found in the study area include: Sierran mixed conifer, montane hardwood, coniferous subalpine, and wet meadows (Mayer and Laudenslayer 1988). Dominant overstory tree species included white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa*), incense cedar (*Calocedrus decurrens*), giant sequoia, and black oak (*Quercus kelloggii*). Topography ranged in elevation from 1219 to 2438 masl.

Study Design. We surveyed for *Accipiters* over two field seasons, during the spring and summer of 2003 and 2004. We followed a systematic design that allowed for equal area coverage, and scaled the sampling units assuming that only one territorial pair per species would be detected in each unit. We created sampling units based on the average home-range size of Sharp-shinned Hawks (i.e., the smaller target species) in western coniferous forest (Bildstein and Meyer 2000). Average home-range size of Sharp-shinned Hawks in this type of habitat was approximately 110 ha; thus, the size of the primary sampling unit (PSU) was approximately 1000 m². We established 30 primary sampling units in the first field season and two survey visits were conducted. In the second field season, we expanded the study area to include 34 PSUs so that MHDSF was completely surveyed. We conducted three

survey visits at 15 PSUs and four survey visits at 19 PSUs during the second field season.

Using ArcView 3.2 (Environmental Systems Research Institute, Redlands, California, U.S.A.), PSUs were overlaid onto a 7.5' topographic quadrangle map. Within each PSU, we established 18 survey station units (SSU) to systematically cover the entire area. Maximum distance between SSU transects was 220 m. We located SSUs along the transect line approximately 200 m apart and offset from adjacent transects by 100 m.

Survey Protocol. We used broadcast acoustical surveys, also known as the broadcast survey method (BSM), to determine occupancy and detection rates (Joy et al. 1994, Woodbridge and Detrich 1994). We broadcast recorded vocalizations of Sharp-shinned and Cooper's hawks at each survey station using a survey CD and amplified speaker. Six researchers were divided into three field crews of two surveyors per crew. Field crews were initially trained as a group on survey protocol and identification of vocalizations and nests. Field crews were rotated every week to ensure quality control.

We conducted surveys from 30 min before sunrise to 30 min after sunset, from 15 May to 30 August. One survey visit was conducted during each of three phases of the breeding cycle (i.e., incubation phase, nestling phase, and fledgling phase) for each sampling unit. The dates for the phases of each breeding period were initially assumed based on existing published information, and refined by repeated observations of behavior at nest sites. The dates for breeding phases for Sharp-shinned Hawks were: 30 May–29 June (incubation), 29 June–5 August (nestling), and 5 August–3 September (fledgling). For Cooper's Hawks, the dates were 16 May–16 June (incubation), 16 June–12 July (nestling) and 12 July–11 August (fledgling).

At each calling station, we broadcast calls 60°, 180°, and 300° from the transect line using 10 sec of vocalization followed by a 30-sec listening period, and rotating the player after each sequence. We conducted this sequence nine times, totaling a 6-min call survey for each species. We played a Sharp-shinned Hawk series first (6 min), followed by the Cooper's Hawk, for a total of 12 min of surveying at each station. We used a combination of alarm and wail calls at each survey station throughout the breeding season, with the first 4 min of the survey using alarm calling followed by the wail call in the last 2 min. Once a detection of either species occurred, the survey was aborted and a nest search

was initiated immediately in the approximate location of the detection. We searched an area (approximate radius = 200 m) around the detection location for any type of sign (i.e., nest structure, excreta, molted feathers, and/or prey remains) for ≤ 120 min.

At each SSU, we recorded date, beginning survey time, ending survey time, and survey visit number. If a species was detected, we noted the time of detection, latency to detection (amount of time since the start of the survey until bird was detected), detection location (survey point or along the transect line between the survey stations), and detection type (SVD-silent visual detection, VNA- vocal non-approach, BVV-both visual and vocal, VAD-vocal approach). In addition, we recorded the number of individuals detected, followed by age and sex if possible, and the estimated distance of the vocalization from the SSU.

Data Analysis. We used program PRESENCE (MacKenzie et al. 2002) to estimate detection probabilities and occupancy rates for Sharp-shinned and Cooper's hawks over multiple survey visits. Detection data (0 for absence, 1 for presence) was entered into the software program using a spreadsheet format (MacKenzie et al. 2002). Detections that fell under the "unknown small *Accipiter* species" category needed to be addressed before this occurred. This category included detections that were either a Sharp-shinned or a Cooper's hawk but could not be identified to species. If the detection was associated with a sampling unit that had a previous and consistent detection of a known species, then the unknown detection was included in the analysis as the species that was present in previous visits. This accounted for most of the unknown detections except one, which was excluded from the analysis. The other unknown category was the "unknown *Accipiter* species," which meant the bird could have been Sharp-shinned Hawk, Cooper's Hawk, or Northern Goshawk. These detections were not included in the analysis.

Each species was run separately through program PRESENCE using two different predefined models: (1) a single-season model where detection probability was constant across all survey visits, and (2) a single-season model where detection probability was not constant, but survey-specific, and varied at all sites and for each of the four survey visits. The assumption of the single-season model is that sampling units are closed to changes in the state of occupancy for the duration of the sampling. We accounted for this by surveying only during the

Accipiter breeding season, when adults were territorial. The two models were then compared using Akaike Information Criterion (AIC) values. A likelihood ratio test was also conducted to test the null hypothesis that detection probability was constant, using a chi-square distribution with $\alpha = 0.05$.

RESULTS

Detections. During the 2003 field season, we surveyed 23 PSUs two times, resulting in 23 detections: 13 Sharp-shinned Hawks, 5 Cooper's Hawks, 3 unknown small *Accipiter* species (Sharp-shinned or Cooper's hawks), and 2 detections of an unknown *Accipiter* species (Sharp-shinned Hawk, Cooper's Hawk, or goshawk). We conducted nine nest searches associated with the detections and located one Sharp-shinned Hawk nest. We located a second Sharp-shinned Hawk nest coincidentally (i.e., located not using the survey protocol).

During 2003, we detected 25 individuals, including 3 adults, 8 juveniles, and 14 birds of unknown age. The number of individuals differed from the number of detections because, in some cases, we detected more than one bird at the same time. We categorized Sharp-shinned Hawk detections as VNA (46%), BVV (46%), or SVD (8%). We categorized Cooper's Hawk detections as VNA (80%) or SVD (20%). As the breeding season progressed, the number of detections increased, varying from three during the incubation phase, to four during the nestling phase, and 16 during the fledgling phase.

During the 2004 field season, we surveyed 19 PSUs four times and 15 PSUs three times. Only 19 of 34 PSUs were surveyed four times due to a wildfire that shortened the field season. We recorded 60 detections including, 26 Sharp-shinned Hawks, 16 Cooper's Hawks, 14 unknown small *Accipiter* species, and 4 unknown *Accipiter* species. We conducted 33 nest searches and located seven nests (four Sharp-shinned and three Cooper's hawk nests).

Of 67 individuals identified, 12 were adults, 14 were juveniles, and 41 were of unknown age. We categorized Sharp-shinned Hawk detections as VNA (26%), SVD (26%), and BVV (48%). We categorized Cooper's Hawk detections as SVD (29%), VNA (29%), and BVV (43%). The number of detections during each breeding phase was 18 during incubation, 13 during nestling, and 29 detections during the fledgling phase.

Occupancy Rate and Detection Probabilities. We analyzed data from the 2004 field season using program PRESENCE; for 2003, we did not have a large

enough sample size to analyze in this way. The naïve estimate of the proportion of sites occupied without using maximum likelihood procedures was 0.38 for the Sharp-shinned Hawk. The constant detection probability model for the Sharp-shinned Hawk estimated the proportion of sites occupied at 0.41 (95% CI = 0.25–0.59), with a detection probability of 0.57 (95% CI = 0.41–0.71). The survey-specific detection probability model for the Sharp-shinned Hawk estimated the proportion of sites occupied at 0.41 (95% CI = 0.25–0.59) and detection probabilities ranging in value between 0.50 (95% CI = 0.25–0.75) and 0.65 (95% CI = 0.36–0.86).

For the Cooper's Hawk, the naïve estimate of the proportion of sites occupied without the model was 0.32. The constant detection probability model for the Cooper's Hawk estimated the proportion of sites occupied to be 0.35 (95% CI = 0.20–0.54), with a detection probability of 0.53 (95% CI = 0.36–0.69). The survey-specific detection probability model for the Cooper's Hawk estimated the proportion of sites occupied at 0.34 (95% CI = 0.20–0.52) and detection probabilities ranging in values between 0.34 (95% CI = 0.13–0.64) and 0.69 (95% CI = 0.37–0.89).

The AIC values for the constant and survey-specific detection probability models for the Sharp-shinned Hawk were 115.1 and 120.1, respectively, indicating that the constant detection probability model fit the data better. The likelihood test supported that result in accepting the null hypothesis that the detection probability was constant ($\chi^2 = 0.98$, $df = 3$). The AIC values for the constant and survey-specific detection probability models for the Cooper's Hawk were 105.3 and 107.13, respectively. Similarly, the constant detection probability model fit the Cooper's Hawk data better. The likelihood test also supported the AIC results by the acceptance of the null hypothesis that the detection probability was constant ($\chi^2 = 4.17$, $df = 3$).

DISCUSSION

Detections. The BSM using two vocalizations in sequence in this study was valuable for detecting both species. Other studies have mostly focused on single species surveys (Henneman et al. 2007, Beck et al. 2011). We found no published studies that surveyed for these two species at the same time to compare with the results of this study. Response type changed across the breeding season. During the incubation period, SVD occurred most often compared to the others (BVV and VNA). During

the fledgling-dependency period, the BVV occurred most frequently. Rosenfield et al. (1985) found similar results, with most of their responses resulting in SVDs during the incubation period, followed by BVV and the VNA the least.

Detection rates can fluctuate across the breeding season depending on the species (Roberson et al. 2005). We found the greatest number of detections occurred during the fledgling phase of the breeding cycle for 2003 and 2004. In 2003, the second greatest number of detections was during the nestling phase. However, in 2004 the second greatest number of detections was during the incubation phase. Some other studies of *Accipiters* have found the greatest number of detections occurring during the nestling and fledgling phases (Rosenfield et al. 1988, Kennedy and Stahlecker 1993, Joy et al. 1994, Watson et al. 1999). However, other studies of Northern Goshawks have shown that the greatest number of detections occurred during the courtship phase of the breeding period (Penteriani 1999; Roberson et al. 2005). We were unable to conduct surveys during the courtship period due to logistical constraints on winter access. Future studies that use our survey techniques should consider conducting surveys during the courtship period, which may provide better estimates of detection probabilities and occupancy.

For some species, response can occur during the nestling and fledgling phase when birds are defending their young in the nest, as opposed to the incubation phase of their breeding period (Penteriani 2001). Presumably, birds are trying to be less conspicuous during the incubation phase to avoid drawing attention to the nest. The courtship phase is another part of the breeding cycle that should be evaluated for detectability of Sharp-shinned and Cooper's hawks. However, this phase was not evaluated in our study due to lack of accessibility to the study area in late winter. The type of detections elicited during each breeding phase supports these hypotheses for 2003. It is unclear why there was a higher response rate during the incubation phase in 2004. This discrepancy may be related to miscalculation of the dates of the incubation phase: surveys conducted late in the time period we classified as incubation may have, in fact, occurred during the nestling phase for some nests and those earlier in that time period may actually have occurred during the courtship phase for some nests.

We found that most responses occurred within 10 min of initiating the calling sequence. Mosher et al.

Table 1. Summary statistics for survey points where birds were detected at Mountain Home Demonstration State Forest, California, U.S.A., by year.

YEAR	STATISTIC	TOTAL MINUTES	LATENCY TO DETECT (MIN)	APPROXIMATE DISTANCE (m)
2004	Mean	8.4	9.3	89.2
	Standard deviation	4.1	16.9	87.8
	Minimum	0.0	0.0	0.0
	Maximum	12.0	12.0	350.0
2003	Mean	12.7	6.1	76.1
	Standard deviation	2.3	6.6	67.4
	Minimum	11.0	0.0	15.0
	Maximum	22.0	30.0	300.0

(1990) found that woodland raptors responded to taped conspecific vocalizations within 10 min of the initiation of calling and usually within 5 min. Rosenfield et al. (1985) reported that Cooper's Hawks responded within 1 min of beginning the survey: most responses occurred within 100 m of the survey station. However, Cooper's Hawks were detected as far as 350 m from the station (Rosenfield et al. 1985). Kennedy and Stahlecker (1993) found that detectability was highest for Northern Goshawks usually within 100 to 200 m of a nest. Beyond 300 m the likelihood of detection was close to zero. However, Watson et al. (1999) found that at 400 m from the calling stations, Northern Goshawks will still respond but the ability of the observer to detect the bird was substantially decreased. The factors of response time and distance should be considered when surveying for these species. The farther the hawk travels, the longer the response time will be.

Results of our study show that detection is possible beyond 300 m but this only occurred once. This could have been due to the vegetation or topography that allowed the response vocalization to carry farther than usual. Also, observer error in estimating the distance to the detection may be an additional factor. Roberson et al. 2005 found that the effective area surveyed per broadcast station was 39.8 ha during the courtship phase of the breeding period and 24.8 ha during the fledgling phase. As a result, their broadcast stations could be spaced 712 m apart during the courtship phase and 562 m apart during the fledgling phase. However, their study was conducted in Minnesota where topography is fairly flat compared to the southern Sierra Nevada. Therefore, topography as well as vegetation density should be considered when determining the appropriate spacing for broadcast stations (Table 1).

Occupancy Rate and Detection Probabilities.

Naïve estimates of presence/absence data for Sharp-shinned and Cooper's hawks indicate that the proportion of sites occupied in 2003 with two visits was 15% and 15.5%, respectively. For 2004 with three to four survey visits, estimates increased to 38% for the Sharp-shinned Hawk and 32% for the Cooper's Hawk. Using the PRESENCE model, which accounts for detection probabilities, the proportion of sites occupied and the detection probability for the Sharp-shinned Hawk was estimated at 0.41 and 0.57, respectively. This suggests that 57% of the time after four survey visits, a Sharp-shinned Hawk will be detected when present. For the Cooper's Hawk, the model estimated the proportion of sites occupied to be 0.25 and a detection probability of 56% after four survey visits.

Using a modeling framework such as PRESENCE where detection probabilities are considered when estimating occupancy, is ideal for hard-to-survey species like the Sharp-shinned and Cooper's hawks.

The two models tested, the constant and survey-specific detection probabilities, did not have drastically different AIC values for the Cooper's Hawk, but did have a moderate difference for the Sharp-shinned Hawk. The difference in AIC values between the two models was 1.83 for the Cooper's Hawk, and 5.02 for the Sharp-shinned Hawk. The AIC weights in the model output clearly showed that the constant detection probability model was most appropriate for the Sharp-shinned Hawk, and the results of the likelihood test support this. For the Cooper's Hawk, although the AIC weight pointed to the constant detection probability model, there was a quarter of the AIC weight distributed to the survey-specific detection probability model. This indicates that even though it wasn't the best model, it should not be completely dismissed, and detection

probabilities may vary between surveys. The survey-specific model for Cooper's Hawk estimated detection probabilities with a large range of variation, from 0.34 to 0.69, but was not the most parsimonious model. MacKenzie et al. (2006) suggests that when this occurs, it is usually an indication of small sample size. This was supported by the fact that most of the occupancy and detection probability estimates have relatively wide confidence intervals. Although the sample size of our study was $n = 34$, we were surveying for two species at the same time that were both detected in low numbers. The sample size would have to be increased considerably in order to obtain better estimates of occupancy and detection probabilities for these two species.

There are no published detection rates for Sharp-shinned and Cooper's hawks using the method we tested; thus, no specific comparisons can be made. Other studies (Kennedy and Stahlecker 1993, Roberson et al. 2005) have estimated detection rates for the Northern Goshawk between 60% and 70% based on one to two survey visits; however, goshawks are more vocal and aggressive throughout the breeding period than the two smaller *Accipiters*. Therefore, one would expect lower detection probabilities for Sharp-shinned and Cooper's hawks. One factor that could potentially play a role in this phenomenon may be that the larger goshawk can prey upon these two species. By vocalizing, they are announcing their location, which may affect frequency of response to conspecific vocalizations. Survey effort would need to substantially increase to estimate occupancy across the landscape for the two smaller *Accipiters*. Even after four survey visits, occupancy and detection probabilities were still <60%. Future studies that utilize this study design should consider running a power analysis using different scenarios, including number of survey visits, and the number of sampling units to achieve an acceptable level of confidence.

Other factors that could affect detection rates of Sharp-shinned and Cooper's hawks are topography, vegetation density, and nesting status. Watson et al. (1999) found that dense understory vegetation and topography can reduce visibility to the observer and increase rate of attenuation of broadcast calls, resulting in lower detection probabilities. Kennedy and Stahlecker (1993) found that detection rates decreased substantially for goshawks that were not nesting the year surveys were conducted.

Factors affecting detection probabilities were not evaluated in this study, but would be a worthwhile question to address in future research. Beck et al.

(2011) estimated occupancy by goshawks across a large area of the Rocky Mountains. Using the Northern Goshawk Bioregional Monitoring Design (Woodbridge and Hargis 2006), they stratified by habitat quality and accessibility. Their estimate of occupancy for the entire study area was 0.329. However, when they stratified the habitat into primary and secondary habitat, their estimates of occupancy were 0.81 and 0.12, respectively. Our sample size and study area were not large enough to stratify by habitat. However, our study serves as an example of a methodology that provides initial estimates of occupancy and detection probabilities, with the sampling frame we used of 34 sampling units surveyed three to four times. This information can be helpful for planning future studies for Sharp-shinned and Cooper's hawks in the Sierra Nevada Mountains in California. By using our study design, which is similar to what is outlined in the Northern Goshawk Inventory and Monitoring Technical Guide (Woodbridge and Hargis 2006), researchers can begin to incorporate other variables that can be included in the PRESENCE model. Other variables could include habitat quality, precipitation, prey abundance, and forest management, all of which affect Sharp-shinned and Cooper's hawk abundance.

Management Implications. This study provides initial estimates of survey effectiveness for the southern Sierra Nevada Mountains in California that can be used by managers to guide design of project level surveys. Projects that strive to estimate occupancy for these species should incorporate detection probabilities since they have imperfect detection <1. Scale and sample size should be considered carefully in the development of a monitoring program. Our intent is that these data should serve as baseline information to aid in designing future long-term monitoring programs for these two species.

Monitoring provides a foundation for informing conservation and management actions, especially on a large scale (Beck et al. 2011). The Sierra Nevada mountain range covers a significant portion of California, and disturbance there is occurring on increasingly large scales. *Accipiter* habitat in the Sierras can be affected by catastrophic wildfires, timber harvest, forest disease outbreaks, and urban development on the west slopes of the Sierra. Incorporating variables such as habitat type, land and forest management, and fire history, as well as detection probabilities, will provide better occupancy estimates for elusive species like the Sharp-shinned and Cooper's hawk. Ongoing, large-scale monitoring programs

can be capable of detecting a level of population change (i.e., 20–30% decline) for the species of interest, with an acceptable level of statistical power.

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