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NESTING HABITAT AND PRODUCTIVITY OF SWAINSON'S HAWKS IN SOUTHEASTERN ARIZONA

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ABSTRACT.—We studied Swainson's Hawks (*Buteo swainsoni*) in southeastern Arizona to assess the status of the local breeding population. Nest success (≥1 young fledged) was 44.4% in 1999 with an average of 1.43 ± 0.09 (SE) young produced per successful pair. Productivity was similar in 2000, with 58.2% nesting success and 1.83 ± 0.09 fledglings per successful pair. Mesquite (*Prosopis velutina*) and cottonwood (*Populus fremontii*) accounted for >50% of 167 nest trees. Nest trees were taller than surrounding trees and random trees, and overall there was more vegetative cover at nest sites than random sites. This apparent requirement for cover around nest sites could be important for management of the species in Arizona. However, any need for cover at nest sites must be balanced with the need for open areas for foraging. Density of nesting Swainson's Hawks was higher in agriculture than in grasslands and desert scrub. Breeding pairs had similar success in agricultural and nonagricultural areas, but the effect of rapid and widespread land-use change on breeding distribution and productivity continues to be a concern throughout the range of the species.

KEY WORDS: *Swainson's Hawk*; Buteo swainsoni; *Arizona*; *breeding success*; *habitat*; *nest-site selection*; *reproductive rate.*

HÁBITAT REPRODUCTIVO Y PRODUCTIVIDAD DE *BUTEO SWAINSONI* EN EL SURESTE DE ARIZONA

RESUMEN.—Estudiamos a *Buteo swainsoni* en el sureste de Arizona para evaluar el estado de la población reproductiva local. El éxito de nidificación (≥1 pichón que deja el nido) fue 44.4% en 1999 con un promedio de 1.43 ± 0.09 (DE) pichones producidos por pareja exitosa. La productividad fue similar en el 2000, con 58.2% de éxito de nidificación y 1.83 ± 0.09 volantones por pareja exitosa. *Prosopis velutina* y *Populus fremontii* representaron >50% de 167 árboles nido. Los árboles nido fueron más altos que los árboles que los rodeaban y que los árboles elegidos al azar, y en general hubo mayor cobertura vegetal en los sitios de nidificación que en los sitios elegidos al azar. Este requerimiento aparente de cobertura alrededor de los sitios de nidificación puede ser importante para el manejo de la especia en Arizona. Sin embargo, cualquier necesidad de cobertura en sitios de nidificación debe ser balanceada con la necesidad de áreas abiertas para forrajeo. La densidad de individuos reproductivos de *B. swainsoni* fue mayor en tierras agrícolas que en pastizales y matorrales desérticos. Las parejas reproductivas tuvieron un éxito similar en áreas agrícolas y no agrícolas, pero el efecto del cambio rápido y extenso de uso del suelo en las distribuciones reproductivas y en la productividad continúa siendo un problema a lo largo de la distribución de la especie.

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The Swainson's Hawk (*Buteo swainsoni*) is an open-country raptor that breeds in grasslands, scrublands, and agricultural land throughout the western United States and Canada (England et al. 1997, Bechard et al. 2010). Swainson's Hawks are a species of conservation concern in many states, with documented declines having occurred in California, Nevada, and Oregon (see Bechard et al. 2010 for review), and in Saskatchewan and Alberta, Canada (Schmutz 1989, Houston and Schmutz 1995). However, populations appear to be stable in Idaho, Washington, Montana, and Colorado (Bechard et al. 2010). Population declines from historical numbers may have been associated with landscape changes and habitat degradation (Houston and Schmutz 1995, Bechard et al. 2010), and with pesticide-related mortalities on the wintering grounds (Woodbridge et al. 1995a, 1995b, Goldstein and Woodbridge 1996). In contrast to reported Swainson's Hawk population declines (Schmutz 1989, Houston and Schmutz 1995, Bechard et al. 2010), Breeding Bird Survey (BBS) data suggest positive trends for the species across most ecoregions in which it occurs, the exceptions being in the Tamaulipan Brushlands, Central Mixed Grass Prairie, Edwards Plateau, and the Boreal Taiga Plains (Sauer et al. 2012). An explanation for the inconsistency of these reports is not clear, but differences may be due to high resolution of data derived from population studies of the species (e.g., Schmutz 1989, Houston and Schmutz 1995) compared to low-resolution data collected from BBS routes.

In Arizona, Swainson's Hawks breed in grassland communities, desert scrub, and agricultural areas, with most breeding pairs concentrated in the southeastern corner of the state (Bednarz 1986). Swainson's Hawk numbers appear to have experienced long-term stability and even a slight increase in Arizona based on Breeding Bird Survey data (Sauer et al. 2012). However, little information exists on the size, distribution, and productivity of Swainson's Hawk populations in Arizona for comparison among areas within the state and throughout their breeding range (Bednarz 1988). This may be especially relevant in light of land use changes; large portions of historic Swainson's Hawk habitat in desert scrub and grassland of the Southwest have been converted to agriculture and may be subjected in the future to energy exploration. Although Swainson's Hawks are known to occupy agricultural areas elsewhere in their range (Schmutz 1987, Woodbridge 1991, Smallwood 1995, England et al. 1997, Briggs 2007), it remains unknown how Swainson's Hawks respond, positively or negatively, to agricultural development in desert environments where water and nest sites may be limiting.

To address these information needs, we surveyed breeding pairs of Swainson's Hawks and monitored nest success throughout southeastern Arizona in 1999 and 2000. Our objectives were to document nesting distribution and density, measure rates of productivity, and assess the status of the local breeding population. We also characterized Swainson's Hawk nest sites in agricultural and nonagricultural (desert scrub and grassland) communities of southeastern Arizona to identify if and how nest sites in agricultural communities differed from the surrounding landscape. Because loss of breeding habitat has been cited as a potential problem for the species, we also compared density of nesting Swainson's Hawks and their productivity between native-vegetation communities and agriculture lands in southeastern Arizona.

METHODS

Historical records indicated that most of the Arizona population of Swainson's Hawks bred in the lowlands of the southeastern part of the state (Bednarz 1986), which falls within Bird Conservation Region 34, Sierra Madre Occidental (North American Bird Conservation Initiative 2000). We surveyed the grassland and desert scrublands in Cochise and Santa Cruz counties, the southern part of Graham and Greenlee counties, and the eastern half of Pima County, Arizona (Fig. 1) for nesting Swainson's Hawks in 1999 and 2000. The study area was characterized by gently sloping alluvial fans and nearly level valley floors, with elevations ranging from 800 to 1500 m and included both private and public lands. Average annual rainfall for the area ranged from 200 to 450 mm with >50% of the rain falling during July to mid-August (Van Devender 1995).

Vegetation cover was predominantly desert grassland, but included areas of Chihuahaun desert scrub, Plains grassland, Great Basin grassland, and Sonoran desert scrub, in decreasing order of prevalence (Brown 1994). Desert grasslands in Arizona have been altered dramatically by the presence of people and livestock. Introduced perennial grasses, woody shrubs, leaf succulents, and cacti have mixed with and replaced the original grass cover (Brown 1994). Cattle grazing and lack of natural fires has exacerbated this trend, increasing both the density and distribution of mesquite (*Prosopis velutina*) and

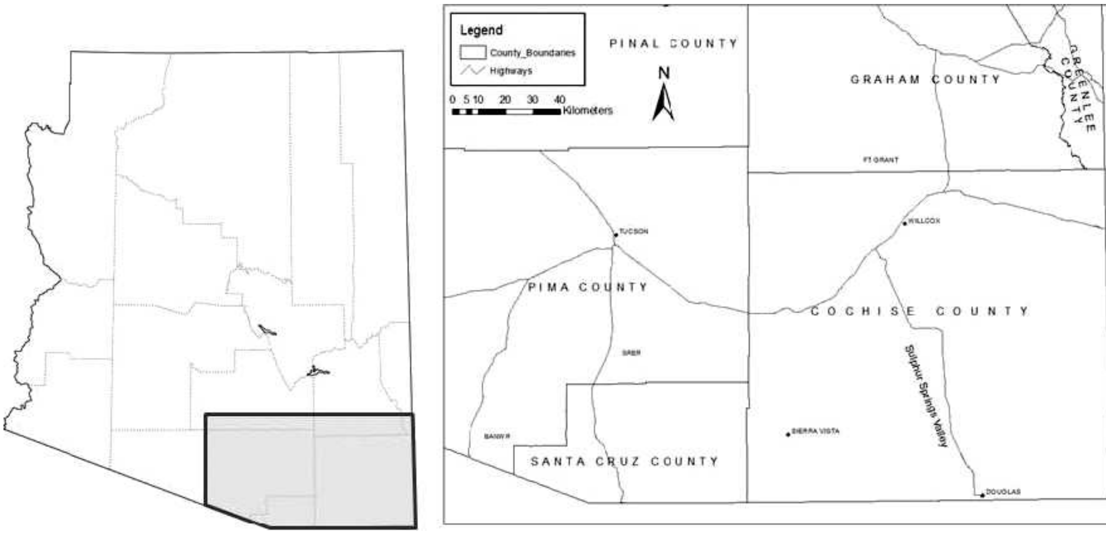

Figure 1. Swainson's Hawk study area in southeastern Arizona, 1999–2000.

other woody shrubs. In addition, portions of the native landscape have been converted entirely to agriculture. Agricultural crop production in the Fort Grant and Sulphur Springs valleys consisted primarily of irrigated cotton, alfalfa, and corn, with lesser amounts of pistachio, pecan, and apple orchards (Arizona Department of Water Resources 2012).

We conducted random and targeted surveys for nesting Swainson's Hawks. For random surveys, we numbered townships within each county and used a random number table to select townships to survey. Townships were removed from the pool of choices if there was no access to the area or if they were adjacent to townships already selected for survey. For targeted surveys, we visited areas known to have high densities of breeding Swainson's Hawks, such as the Sulfur Springs Valley in Cochise County and the Buenos Aires National Wildlife Refuge (BANWR), to ensure these key areas were not omitted by random chance.

We primarily surveyed by vehicle using the existing road systems to cover the large areas necessary to adequately sample populations of large birds of prey (Andersen 2007). We drove all survey roads at approximately 15–25 km hr^{-1}. Because not all nests could be located from roads, we used walking surveys to cover roadless areas when hawks were spotted and nesting activity was suspected.

We found nests by initiating searches in the winter before deciduous trees leafed out. Surveys began in March during the 1999 breeding season and in mid-January during 2000 and continued through July in both years. We used a Global Positioning System (GPS) Unit to record the location of all stick nests found. These nests were then checked for occupancy monthly and new nests were located when pairs were observed engaging in reproductive behaviors (e.g., courtship flights, nest building). Nests in the Fort Grant and Sulphur Springs valleys were considered within agricultural lands. All other nests were found in contiguous tracts of grassland or desert scrub. We considered Swainson's Hawks to be engaged in a breeding attempt if an adult hawk was seen in an incubation or brooding position on the nest in the initial or a subsequent nest check.

We monitored most nests every 7–10 d, but some only at 14-d intervals due to logistical challenges. We calculated nest success using the Mayfield method (Mayfield 1961, 1975). We used binoculars and a spotting scope to check nests from a distance to reduce disturbance, and counted nestlings visible during each visit. We calculated nesting success and fledglings per breeding attempt on the basis of considering nestlings surviving to 80% (34 d) of their average fledging age (43 d; Bechard et al. 2010) as having survived to fledge (Steenhof and Newton 2007). We estimated ages of Swainson's Hawk nestlings based on aging guides for raptors of similar nestling lengths (Moritsch 1983, Boal 1994).

We used a rangefinder and clinometer to measure tree and nest heights above the ground for all nest trees; we were able to do this for nest trees from a distance if we did not have permission to access the property. For those sites where we had access permission, we obtained diameter at breast height (DBH), the number of sides of the nest exposed, direction of exposure, and percentage of the tree that was alive. We defined exposure as a lack of vegetative cover such that the flight of a hawk into the nest was unimpaired.

We characterized nesting habitat by measuring and comparing vegetation and landscape variables at a subsample of nests and paired random sites within 0.03 ha (10-m radius) and 1.1 ha (60-m radius) circular plots centered on the nest tree or random tree. These distances seemed sufficient to capture characteristics of nest sites given the structural simplicity of the environment. We made all measurements in July and August each year after nests had fledged or failed. We measured a subsample of nests (45 in 1999, 29 in 2000) located on both public lands and private land for which we had permission to access; roughly equal numbers of nests were selected from each grouping of either within or away from agricultural lands.

We counted and identified all trees and shrubs within the 0.03 ha plots. We differentiated trees from shrubs by considering trees as >3 m in height with a DBH >3 cm. We recorded the height of all shrubs to the nearest 0.1 m, whereas we assigned trees to height classes based on 5-m intervals and recorded the DBH. We recorded the percentage of surface area that was bare ground, subshrubs, and grass/herbaceous plants.

We selected a random site for each nest tree to compare vegetation characteristics at nest sites to what was available randomly. Random sites were selected by spinning a compass to determine a random direction away from the nest tree; the distance was determined as one of six distances (0.4 to 0.8 km) away from the nest tree represented by the roll of a six-sided die. These distances were chosen because they were large enough to be outside the immediate influence of the nest tree, but small enough to be within the home range of a Swainson's Hawk pair (Bechard et al. 2010). Because Swainson's Hawks in Arizona place their nests no lower than 2 m from the ground (Glinski and Hall 1998), once we reached the random location, we chose the closest potential nest tree or shrub >2 m in height as the random focal point.

To characterize vegetation cover within a 1.1-ha plot at nests and random sites, we used a laser range finder to measure 60 m from the plot center in four cardinal directions. In each of the resulting four quarters, we visually estimated percentage cover of trees and shrubs by species, grass/herbaceous cover, and bare ground. Lyon (1968) suggested that visual estimation provides a realistic means to assess vegetation density in shrub communities. We estimated tree cover within 5-m height intervals.

We used chi-squared tests to compare success rates between years and between land-cover types. We determined distances between nests with ARCINFO Geographic Information System (GIS) software (ESRI 1998). Nests greater than 5 km away from any other nest were omitted from calculations of internest distances. We used paired *t*-tests to compare the heights of nest trees to paired random trees. Two-sample *t*-tests were used to compare the heights of nest trees that produced young with those that failed. We also used *t*-tests to compare nest trees to other trees within the 0.03-ha plots. These comparisons were made between the nest tree and all other species, and then restricted to comparisons of the nest tree only with trees of the same species.

We built conditional logistic regression models for case-control studies (Hosmer and Lemeshow 1989) to evaluate if the presence of a nest was related to vegetation cover. Total summed tree cover for all height classes was included as a single variable. Before analyses, we screened explanatory variables for multicollinearity; none of the variables used in the model were statistically correlated ($r < 0.52$). We first fit full models with all cover variables and then used backwards elimination ($P < 0.10$) to determine the final model.

We used JMP 4.0 software (SAS Institute 2000) to analyze all data except for the models built using logistic regression for matched case-control studies. For this special case of logistic regression, we used the PROC LOGISTIC function in SAS to develop the models (SAS Institute 1999). The level of significance used was $P < 0.05$ and all values are expressed as arithmetic means $\pm$ SE.

RESULTS

We surveyed for Swainson's Hawks over a total of 4425 linear km in southeastern Arizona during 1999 and 2000. Foot surveys (1089 km) accounted for 25% of effort and vehicle surveys (3336 km) accounted for 75% of effort. Random survey effort accounted for 55% and targeted surveys accounted for 45% of the distance covered. We found 61

Table 1. Characteristics of Swainson's Hawk nests in southeastern Arizona, 1999–2000.

CHARACTERISTIC	n	MEAN	SE
Nest tree height (m)	145	9.84	0.44
DBH (cm)	77	44.12	4.62
Nest height (m)	144	7.41	0.35
Ratio of nest/nest tree	116	0.76	0.01
No. of sides exposed	77	3.6	0.09
Amount of nest tree alive (%)	77	82.8	3.23
No. of support branches	70	6.63	0.21

Table 2. Vegetative cover features that influence the presence of Swainson's Hawk nests in southeastern Arizona, 1999–2000[a].

FACTOR	β	SE	ODDS RATIO
Tree	0.10	0.04	1.16
Shrub	0.09	0.03	1.14
Subshrub	0.08	0.04	1.12
Grass and herbaceous	0.06	0.02	1.11

[a] Results are from a conditional logistic regression model (χ^2_4 = 13.7, P = 0.01, n = 73).

Swainson's Hawk nests with breeding attempts in 1999 and 106 nests in 2000, and all nests were located in Cochise, Graham, and Pima counties. There was no difference in nesting success between nests found during foot or vehicle surveys (χ^2_1 = 0.6, P = 0.45) or between nests found by random or targeted surveys (χ^2_1 = 0.7, P = 0.42). Because there was no difference in nest success among the different survey efforts, we combined nests within years for all further analyses.

Mayfield adjusted nest success estimates were not statistically different (χ^2_1 = 3.0, P = 0.08) between 1999 (44.4%, 95% CI = 44.0–44.8%) and 2000 (58.2%, 95% CI = 58.0–58.4%). Mean number of fledglings per nest was lower (t_{165} = −2.4, P = 0.02) in 1999 (0.85 ± 0. 12; n = 61 nests) than in 2000 (1.23 ± 0.09; n = 106 nests). Similarly, when considering only successful nests, the mean number of young fledged was lower (t_{106} = −3.2, P < 0.01) in 1999 (1.43 ± 0.09; n = 37 nests) than in 2000 (1.83 ± 0.09; n = 71 nests). There was no difference in nest success (χ^2_1 = 0.6, P = 0.43) or in the number of fledglings per nest (t_{165} = 1.2, P = 0.24) between the nests in agricultural lands (n = 89) and those in grasslands and desert scrub (n = 78) for both years combined. Swainson's Hawk nests averaged 2.3 km (95% CI = 2.1 to 2.5 km) apart, with a nearest inter-nest distance of 488 m. Nearest neighbor distances between nests in agricultural lands (2.1 ± 0.1 km) and in grasslands and desert scrub (2.4 ± 0.1 km) were not significantly different (t_{136} = −1.5, P = 0.07).

We measured nest (n = 145) and nest tree (n = 144) heights, and measured vegetation characteristics within 0.03-ha and 1.1-ha plots at a subsample of 74 nests and paired random locations in agricultural areas (n_{Ag} = 36) and grassland-desert scrub areas ($n_{Non\text{-}Ag}$ = 38).

Nests were most frequently constructed in mesquites (32%) in natural areas, and shelterbelt trees such as cottonwoods (*Populus fremontii*; 26%), elms (*Ulmus* spp.; 8%), and willows (*Salix* spp.; 7%) in agricultural areas. Trees chosen by Swainson's Hawks for nesting (Table 1) were 4.4 ± 0.8 m taller than paired random trees (t_{55} = 5.2, P < 0.01) and were 0.9 ± 0.2 m taller than all other trees within a 10-m radius (t_{38} = 5.7, P < 0.01). This pattern held when restricting comparisons to trees of the same species; nest trees were 2.8 ± 0.5 m taller than paired random trees of the same species (t_{31} = 5.2, P < 0.01) and 0.6 ± 0.2 m taller than all other same-species trees found within a 10-m radius of the nest tree (t_{27} = 4.1, P < 0.01). Even though most nests were moderately to well concealed, many were still exposed on three to four sides (Table 1) and 10 nests were built in snags with no cover at all. There was no apparent relationship between nest tree height and success of a nest (t_{159} = 0.3, P = 0.77).

There was more vegetative cover within the 0.03-ha nest site plots than in the paired random site plots (χ^2_2 = 6.7, P = 0.04). These plots at nest sites contained more trees (odds ratio = 1.22, P = 0.05) and less bare ground than those at random sites (odds ratio = 0.98, P = 0.05). The 1.1-ha plots around nests contained more vegetative cover of all categories compared to paired random plots (Table 2).

DISCUSSION

The status of Swainson's Hawks in Arizona is unclear. Relative to our study area, BBS data (Sauer et al. 2012) indicate positive population trends from 1966–2011 within the Sierra Madre Occidental ecoregion (1.5, 95% CI = −2.0–4.9), the Chihuahuan Desert (2.7, 95% CI = 1.3–4.3), and the Sonoran Desert (0.8, 95% CI = −6.4–7.6). Unfortunately, BBS data for the species within these sample areas have deficiencies (Sauer et al. 2012); for example, there are only 1340-km routes surveyed in the Sierra Madre Occidental ecoregion (Sauer et al. 2012). During our surveys of 4425 km, we located 106 active Swainson's Hawk nests in 2000. Although a very coarse interpretation, this equates to a nesting pair every 42 km.

Comparing reproductive rate between our study and others was challenging due to different methods employed. We could not reliably compare our data to studies from Wyoming (Dunkle 1977), North Dakota (Gilmer and Stewart 1984), California (England et al. 1995, Woodbridge et al. 1995a), or Saskatchewan and Alberta (Houston and Schmutz 1995) because they only reported observed nesting success derived from variable criteria. In Colorado, Andersen (1995) reported an average of 48% nesting success based on Mayfield nest survival estimates, which is similar to our Mayfield estimated success rates of 44–58%. The only data from our study area is that of Porton (1977), who reported an observed success rate of 55% for 11 nests.

Hawk reproductive rate is known to fluctuate among years in response to environmental conditions (Newton 1979, Smith et al. 1981). In our study area, low winter rainfall in particular may have influenced productivity of Swainson's Hawks through effects on their primary prey. We believe that monitoring of population trends in this region may be warranted. The area is predicted to experience protracted periods of drought and increasing aridity under current climate change models. If these models are accurate, the pattern of nesting success we observed may not persist, and subsequently could result in changes in local population trends.

Areas that hawks selected for nesting varied throughout the southeastern portion of the state. In grasslands and shrublands, Swainson's Hawks nested in open areas interspersed with mesquites and various combinations of shrubs. In agricultural areas, hawks nested where suitable trees were available; these were often trees that had been planted for shade or in shelterbelts.

Swainson's Hawks in Oregon, Washington, Idaho, Wyoming, and Montana used isolated trees of any size provided they offered a vantage point to observe their surroundings (Dunkle 1977, Bechard et al. 1990). Swainson's Hawks in Arizona used both isolated trees and the tallest tree in a cluster. Nest height in larger trees may make nests less accessible to some types of predators, offer hawks a better vantage point to watch their breeding areas, allow more moderate temperatures for egg and nestling thermoregulation, or enhance lift capabilities leading to more efficient prey returns (Smith and Murphy 1982). Additionally, larger trees may provide more supporting branches for nest placement.

Although the difference between nest sites and random points for any individual vegetation variable was small, nest sites had significantly more vegetation than paired random sites when all vegetation categories were combined. Greater vegetation at nest sites may be associated with site-specific edaphic conditions that produce suitable nest trees. If Swainson's Hawks favor more vegetation for nesting, mesquite invasion into grasslands may have increased the potential nesting habitat for this hawk. Historically, grasslands in southeastern Arizona were more open (Hastings and Turner 1965).

Swainson's Hawks appear to adapt well to some altered landscapes. Schmutz (1987, 1989) found that Swainson's Hawks in southeastern Alberta had higher productivity in agricultural areas than in nonagricultural areas. In Oklahoma, Swainson's Hawks used habitat cover types, most of which were in grain agriculture, in proportion to availability (McConnell et al. 2008). We found nest success and the number of young per nest were comparable between agricultural communities and desert scrub and grasslands.

Different agricultural crops may have differing effects on hawk productivity. Home-range studies in rural areas of California found that Swainson's Hawks selected alfalfa, fallow fields, and dryland pasture; resources within these field types can change depending on the growth, maturity, and harvest of the crops (Babcock 1995). England et al. (1995) and Briggs et al. (2011) suggested that agriculture fields were important foraging areas, and increasing distance between fields and nests may result in a reproductive cost. We found Swainson's Hawks in Arizona near alfalfa and fallow fields, but we also found nests near orchards, vineyards, cornfields, cotton, peppers, and other denser crop fields. Although the latter group of crop types may be more difficult to use for foraging, they may still be important to Swainson's Hawks. Smallwood (1995) noted that although vineyards and orchards are generally considered poor foraging grounds for Swainson's Hawks, they still provide habitat for prey.

Smallwood (1995) found that agriculture might benefit Swainson's Hawks provided that key resources are stabilized. This may be true for the Arizona population as well; southeastern Arizona is a desert environment characterized by years of drought interspersed among years of good rains. Irrigation of agricultural lands and, therefore, a steady source of water, may help to stabilize prey populations between years. If this is true, agricultural areas may serve as a buffer against declines in Swainson's Hawk populations at the current levels of development.

We found Swainson's Hawks in Arizona nesting in a variety of trees in both agricultural communities and in grasslands and desert scrub. Increases in the number and density of potential nest trees have occurred in both areas because of fire suppression and human settlement. In agricultural communities, people often plant trees as shelterbelts around their houses. In desert grasslands, encroachment of species such as mesquite and acacias (*Acacia* spp.) have made grasslands less open (Brown 1986), but may have also provided more nest trees for hawks. Swainson's Hawks appear to select sites with more cover as nest sites, and so an increase in cover may encourage nesting, but further study is necessary to determine how Swainson's Hawks are responding to the encroachment of trees which may increase the abundance of potential nest sites, but reduce the abundance of open foraging areas. Our study provides a baseline on the breeding ecology of Swainsons's Hawks in southeast Arizona. Given the potential for further development in rural areas and for environmental changes associated with climate change and energy development, it may be prudent to conduct new surveys and monitoring to compare and assess changes since our study.

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