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Source: Journal of Raptor Research, 50(4) : 338-350

Published By: Raptor Research Foundation

URL: https://doi.org/10.3356/JRR-15-22.1

J. Raptor Res. 50(4):338–350

SPATIAL ECOLOGY AND SURVIVAL OF SWAINSON'S HAWKS (*BUTEO SWAINSONI*) IN THE NORTHERN GREAT PLAINS

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ABSTRACT.—In recent years, anthropogenic conversion of grassland habitat has raised concerns about the status of breeding Swainson's Hawks (*Buteo swainsoni*) in the northern Great Plains region of North America. During 2013–2014, we captured breeding Swainson's Hawks in north-central South Dakota and south-central North Dakota to estimate home-range size, determine adult survival rates during the breeding season, and evaluate habitat selection. We captured, radio-tagged, and monitored 13 Swainson's Hawks in 2013, and captured two additional Swainson's Hawks in 2014. In 2014, seven of 13 individuals initially captured in 2013 returned to the same breeding territory for the 2014 breeding season. Average 95% MCP home-range size in 2013 was 205.4 ha (SD = 135.3 ha, $n = 10$) and 211.1 ha (SD = 208.8 ha, $n = 9$) in 2014, and size did not differ between years ($t_{13} = 0.07$, $P = 0.95$), averaging 208.3 ha (SD = 244.9 ha, $n = 19$ home ranges measured for 12 birds) for the 2 yr of the study. Mean core home-range size (50% MCP) was 78.2 ha (SD =105.9 ha, $n = 10$) in 2013 and 59.7 ha (SD = 80.7 ha, $n = 9$) in 2014; core home-range areas also did not differ between years ($t_{17} = -0.46$, $P = 0.65$). Swainson's Hawks did not select habitats in proportion to their availability in 2013 ($\chi^2_{42} = 781.99$, $P < 0.001$) and 2014 ($\chi^2_{40} > 999.99$, $P < 0.001$). In 2013, breeding Swainson's Hawks selected against wetland and grassland habitats and selected for trees as foraging habitats. Similarly, Swainson's Hawks selected against grassland habitats for foraging in 2014. We used known-fate analysis in Program MARK to estimate adult survival during the breeding season. The top-ranked model indicated survival was constant at 0.94 (95% CI = 0.68–0.99) during the breeding season and did not differ between years. Our results suggest that Swainson's Hawks maintain a moderately high degree of breeding-site fidelity and have home ranges smaller than those documented elsewhere, and that their home-range size is influenced positively by the presence of grasslands and negatively by development.

KEY WORDS: *Swainson's Hawk*; Buteo swainsoni; *breeding*; *habitat selection*; *home range*; *site fidelity*.

ECOLOGÍA ESPACIAL Y SUPERVIVENCIA DE *BUTEO SWAINSONI* EN EL NORTE DE LAS GRANDES LLANURAS

RESUMEN.—En años recientes, la conversión antrópica de los pastizales ha generado preocupación sobre el estatus de las poblaciones de *Buteo swainsoni* en la región septentrional de las Grandes Llanuras de América del Norte. Durante el período 2013–2014 capturamos individuos reproductivos de *B. swainsoni* en el centro norte de Dakota del Sur y en el centro sur de Dakota del Norte para estimar el tamaño del área de campeo, determinar las tasas de supervivencia de los adultos durante la época reproductiva y evaluar la selección de hábitat. Capturamos, instalamos equipos de seguimiento de radio y seguimos 13 ejemplares de *B. swainsoni* en 2013, y capturamos dos individuos más en 2014. Siete de 13 individuos capturados en 2013 retornaron al mismo territorio de cría en la temporada de cría de 2014. El área de campeo de acuerdo con el promedio del Mínimo Polígono Convexo (MPC) al 95% fue de 205.4 ha (DE = 135.3 ha, $n = 10$) en 2013 y de 211.1 ha (DE = 208.8 ha, $n = 9$) en 2014, y el tamaño no difirió entre años ($t_{13} = 0.07$, $P = 0.95$), promediando 208.3 ha (DE = 244.9 ha, $n = 19$ áreas de campeo medidas para 12 aves) para los dos años de estudio. El tamaño

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promedio de las zonas núcleo del área de campeo (MPC 50%) fue de 78.2 ha (DE =105.9 ha, $n = 10$) en 2013 y de 59.7 ha (DE = 80.7 ha, $n = 9$) en 2014. Las superficies de las zonas núcleo de las áreas de campeo tampoco difirieron entre años ($t_{17} = -0.46$, $P = 0.65$). Los ejemplares de *B. swainsoni* no seleccionaron los hábitats en proporción a su disponibilidad en 2013 ($\chi^2_{42} = 781.99$, $P < 0.001$) ni en 2014 ($\chi^2_{40} > 999.99$, $P < 0.001$). En 2013, los individuos reproductivos de *B. swainsoni* seleccionaron negativamente los humedales y pastizales, prefiriendo los árboles como hábitats de alimentación. De modo similar, en 2014 seleccionaron negativamente los pastizales para su alimentación. Utilizamos el análisis de final conocido en el programa estadístico MARK para estimar la supervivencia de los adultos durante la época reproductiva. El mejor modelo indicó que la supervivencia fue constante a 0.94 (95% CI = 0.68-0.99) durante la época reproductiva y no difirió entre años. Nuestros resultados sugieren que *B. swainsoni* mantiene un grado relativamente alto de fidelidad al lugar de cría y tiene áreas de campeo más pequeñas que las documentadas en otros lugares, y que el tamaño de las mismas está influido positivamente por la presencia de pastizales y negativamente por el desarrollo antrópico.

[Traducción del equipo editorial]

Swainson's Hawks (*Buteo swainsoni*) in the northern Great Plains nest in high densities (Lokemoen and Duebbert 1976, Gilmer and Stewart 1984, Hagen et al. 2005, South Dakota Game, Fish and Parks 2005). However, the status of breeding Swainson's Hawks in the northern Great Plains has not been assessed for over 30 yr (Gilmer and Stewart 1984). Swainson's Hawks are characterized as exhibiting high survival, low reproductive rates, and delayed reproduction (Pianka 1970, Briggs et al. 2011). Mass mortalities, such as those documented in their wintering range in Argentina (Goldstein et al. 1996), have been suggested as a primary cause of population decline (Goldstein et al. 1999). Other factors (i.e., intrinsic and extrinsic) may be important parameters to consider when assessing survival within a population. Intrinsic variables such as individual health, age, and sex (McCleery et al. 2008, Briggs et al. 2011) may affect survival during the breeding season. Extrinsic variables (e.g., habitat, competition; Horak and Lebreton 2008) also may affect survival due to the lack of available foraging and nesting habitats.

Currently, state and federal agencies have the Swainson's Hawk listed as a species of concern in the northern Great Plains primarily due to the significant loss of grassland habitat (Hagen et al. 2005, South Dakota Game, Fish and Parks 2005, United States Fish and Wildlife Service 2008, 2011). Estimates of grassland lost from 2007–2013 were 12,020 km^2 in North Dakota and South Dakota (Wright and Wimberly 2013, United States Department of Agriculture 2015). These ongoing changes around nest sites have the potential to affect survival (e.g., displacing prey communities, increasing or changing predator populations, or increasing competition). Farming and ranching practices on remaining grasslands also are a potential concern; increased cattle production and infrequent haying could alter foraging habitats (Johnson and Horn 2008). However, agriculturally rich habitats may increase reproductive rates more than habitats lacking agriculture and potentially provide a stabilized prey base (Schmutz 1987, 1989, Smallwood 1995). Continued expansion of intensive agriculture raises concerns about potential effects on grassland raptors during the breeding season. However, published reports conflict on whether crop production contributed to population declines across much of the Swainson's Hawk range (Bloom 1980, Gilmer and Stewart 1984, Schmutz 1987, Bechard et al. 1990, Nishida et al. 2013).

Resource selection of a particular habitat and home-range size can vary greatly due to factors such as habitat fragmentation (e.g., cropland, farming techniques), prey availability, nest location, and vegetation height (Bechard 1982, Schmutz 1987, Preston 1990, Babcock 1995). In California, Swainson's Hawks sometimes maintain large home ranges (4038 ha) due to the lack of available foraging habitats near nest sites (Babcock 1995). Descriptions of raptor habitat use indicate that foraging is not related to prey density but may be affected by a suite of environmental factors such as habitat characteristics and prey availability (Bechard 1982, Preston 1990). Classic foraging theory predicts that predators forage in habitats requiring the least amount of energy spent per hunting effort regardless of prey densities (Royama 1970). A constantly changing landscape may have the potential to affect habitat selection as habitats are altered for agricultural expansion.

Due to the potential effects of continued agricultural expansion in this grassland ecosystem (Loke-

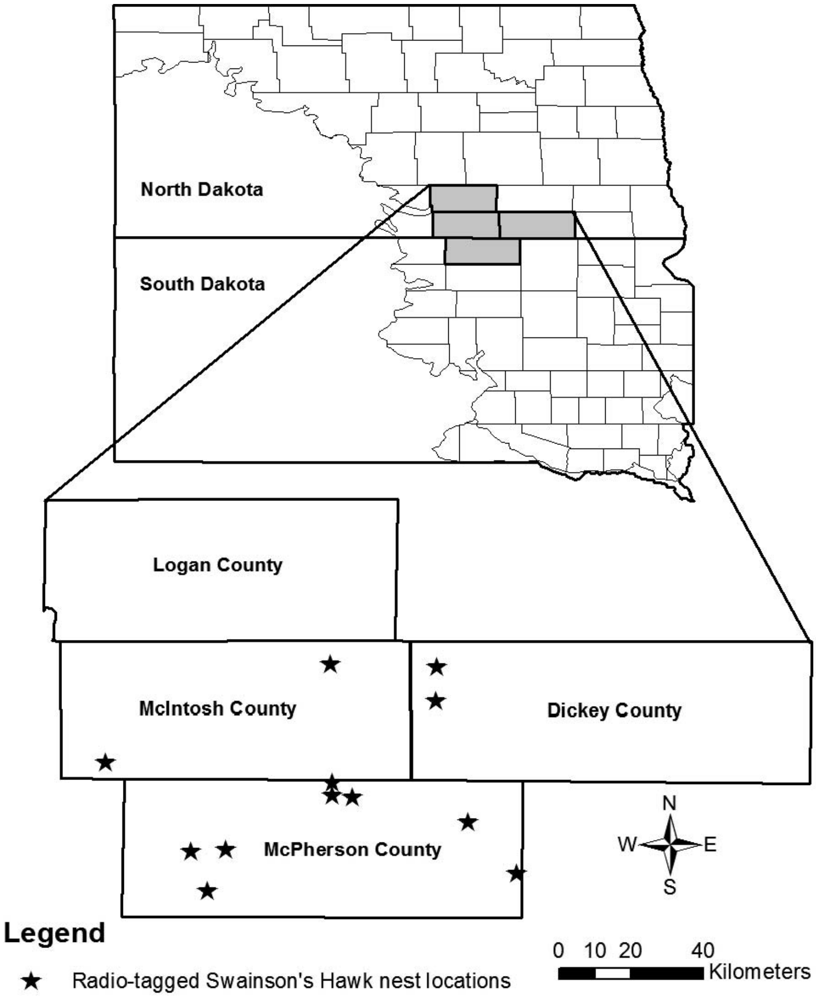

Figure 1. Swainson's Hawk spatial ecology study area in south-central North Dakota and north-central South Dakota, U.S.A., 2013–2014.

moen and Duebbert 1976, Gilmer and Stewart 1984), we investigated the space use and survival of breeding Swainson's Hawks. The objectives of our study were to determine home-range sizes, breeding-site fidelity, and survival rates of breeding Swainson's Hawks. We also provide information on foraging habitat selection at the home-range scale and address the potential effects of habitat on home ranges of Swainson's Hawks in the prairie grasslands of the northern Great Plains.

STUDY AREA

We conducted our work in an 11,137-km^2 study area in south-central North Dakota and north-central South Dakota (Fig. 1). Our study area lies within the Northern and Northwestern Glaciated Plains level III Ecoregion (Bryce et al. 1998). This moraine landscape contains numerous pothole wetlands scattered among the rolling terrain, which is characteristic of the Missouri Coteau Region (Lokemoen and Duebbert 1976, Bryce et al. 1998). Land-cover types in the study area included grassland (44.2%), cultivated land (43.6%), and wetlands (8.6%), with the remaining land made up of development (2.9%) and forest (0.7%; United States Department of Agriculture 2014b). Cultivated lands consisted of 30.7% row crop (corn and soybeans) and 7% alfalfa/hay; the remaining 5.9% consisted of wheat and oats. Average high and low temperatures for the months of April through July ranged from 11.6–29.3°C and –0.5–14.4°C, respectively. Average yearly precipitation during the study was 47 cm, with the majority of precipitation events occurring during May to September (North Dakota State Climate Office 2012). Dominant native vegetation consisted of western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), northern reedgrass (*Calamagrostis stricta*), prairie cordgrass (*Spartina pectinata*), big bluestem (*Andropogon gerardii*), porcupine grass (*Stipa spartea*), and little bluestem (*Schizachyrium scoparium*). Tree species were primarily cottonwood (*Populus deltoides*), American elm (*Ulmus americana*), box elder (*Acer negundo*), and green ash (*Fraxinus pennsylvanica*).

METHODS

We opportunistically trapped nesting pairs of Swainson's Hawks foraging or perched near roads during the nest initiation phases (1 May to 10 June) of the 2013 and 2014 breeding seasons. We targeted breeding pairs early in the breeding season to document Swainson's Hawk spatial ecology for the entire breeding season. We used a modified bal-chatri trap (Berger and Mueller 1959) constructed using 1.27-cm mesh hardware cloth resulting in a hemi-cylindrical shape (30.5 cm long × 25.4 cm wide × 15.24 cm high) with 15.8-kg monofilament nooses approximately 4-4.5 cm in diameter. All traps contained two live house mice (*Mus musculus*) as bait. We made trapping attempts from vehicles in view of raptors on the side of roads, monitoring from close proximity for immediate radio-tagging and release of captured raptors.

We fitted captured birds with Very High Frequency (VHF) radio transmitters (Model 1135; Advanced Telemetry Systems, Isanti, MN U.S.A.) with unique frequencies. We used a backpack-style harness that attached the transmitter to the synsacrum of the bird (Rappole and Tipton 1991, Mallory and Gilbert 2008). We only radio-tagged individuals when the transmitter weight was less than 3% of total body mass (Phillips et al. 2003). Each adult was also fitted with a numbered aluminum United States Fish and Wildlife Service lock-on band (Federal bird banding permit #21408). We determined sex of captured hawks using a combination of morphological measurements including mass, footpad length, and wing chord length (Kochert and McKinley 2008). We classified birds as female or male if measurements in two of three categories were within the measurement ranges established for each sex by Kochert and McKinley (2008). All animal handling procedures followed guidelines of the Ornithological Council (Fair et al. 2010) and were approved by the Institutional Animal Care and Use Committee at South Dakota State University (Approval No. 13-002A), South Dakota Game, Fish and Parks (Permit #14), and the North Dakota Game and Fish Department (Permit #GNF03541963).

We located radio-tagged individuals using R-1000 handheld receivers (Communications Specialists Inc., Orange, CA U.S.A.), a R2000 receiver (Advanced Telemetry Systems), truck-mounted omnidirectional antennas, and hand-held 4-element Yagi antennas. We visually located each bird 2–3 times per week on a rotational daytime schedule using 8-hr intervals to avoid obtaining locations during the same interval on successive attempts (i.e., 0630–1430 H and 1430–2230 H).

We also intensively monitored birds twice during the breeding season, once during incubation and once after hatching (Bechard 1982, Andersen and Rongstad 1989, Babcock 1995). Intensive monitoring sessions consisted of recording a location every hour for 8 hr. We conducted sessions from 0600–1400 H or 1400–2100 H, ensuring that we monitored every bird for one morning and one evening session. We conducted the first period of intensive monitoring from 10 June–25 June and the final period from 10 July–25 July. To avoid autocorrelation of locations during intensive monitoring, we ensured that $\geq$1 hr passed between successive relocations (Andersen and Rongstad 1989, Babcock 1995). Collecting locations during intensive and weekly monitoring ensured that we collected enough locations throughout the season and confirmed that weekly monitoring locations collected 2–3 times per week provided an accurate representation of foraging patterns. For home-range estimations, we only recorded bird locations if the bird was visually located (Babcock 1995); locations in the nest tree were excluded. Relocations used to analyze habitat selection were included only if we observed the bird foraging (Bechard 1982). We recorded all locations on National Agriculture Imagery Program (NAIP; United States Department of Agriculture 2014a) maps created in ArcGIS 10.1 (ESRI 2011). We recorded locations of individuals based on the approximate location of the bird over a specific landscape feature with the assistance of optics and rangefinders. The availability of roads around nest sites allowed us to be $\leq$800 m from birds when recording locations and

Table 1. Final variables measured within 100% minimum convex polygon (MCP) home ranges and the percent composition of habitat variables for the entire study area of breeding Swainson's Hawks in the northern Great Plains, U.S.A., 2013–2014.

VARIABLE NAME	DEFINITION	LAND COVER (% OF THE ENTIRE STUDY AREA)
Grass	Total grassland and pasture (%)	44.2
Row crop	Total corn and soybean cover (%)	30.7
Wetland	Total wetland cover (%)	8.6
Hay	Total alfalfa/grass hay cover (%)	7.0
Grain crop	Total grain crop cover (%)	5.9
Development	Total farm sites and roads (%)	2.9
Trees	Total tree cover (%)	0.7

the availability of landscape features (e.g., tree belts, rock piles) increased our accuracy. We then referenced recorded locations with ArcGIS 10.1 to determine the coordinates of each location. For each location, we recorded additional field observations: date, time, habitat, behavior (e.g., hunting, perched), and any additional observed behaviors.

We used a 95% minimum convex polygon (MCP) to delineate breeding home range as well as 50% MCP to define core-use areas for Swainson's Hawks using the adehabitatHR package (Calenge 2011) in program R (R Development Core Team 2009). We used the Cropland Data Layer (CDL; United States Department of Agriculture 2014b) to evaluate land use within home ranges. We reclassified the CDL layers from 2013 and 2014 to represent the land-cover variables we assessed as biologically significant from published literature (e.g., Bechard 1982, Gilmer and Stewart 1984, Babcock 1995): row crop, grain crop, alfalfa/hay, grassland, water, trees, and farm sites. The reclassification process allowed us to simplify the analysis by combining similar vegetation/habitats (e.g., corn and soybeans considered "row crop"). We clipped reclassified CDL layers to MCP home ranges for each animal using Geospatial Modeling Environment (Beyer 2012) and calculated land-cover percentages for each land cover type using ArcGIS 10.1 (ESRI 2011). We used a two-sample *t*-test to evaluate whether home-range size (95% and 50% MCP) differed between years or sexes.

We used the kernel overlap function in the adehabitatHR package (Calenge 2011) in program R to calculate utilization distribution overlap indices (UDOI; Fieberg and Kochanny 2005) of birds that returned to the same nest sites in the second year of the study to evaluate breeding-site fidelity. This method calculates the product of an animal's utilization distribution (UD) for each animal each year and then compares the distribution of the independent UDs to determine space-use overlap (Fieberg and Kochanny 2005). Home-range overlap for UDOI analysis is equal to zero for no overlap and 100% (1.0) for complete overlap for uniformly distributed home ranges (Fieberg and Kochanny 2005). Home ranges for UDOI may be >1 if the two home ranges are nonuniformly distributed on the landscape associated with a high degree of overlap (Fieberg and Kochanny 2005).

We used linear mixed-effects models to test the influence of Swainson's Hawks chosen habitat types on home-range size (Table 1). We generated 13 models from field observations that we believed to be biologically significant in interpreting variation in home-range size. We included the variable "territory" as a random effect to determine whether variability in habitat within home ranges was related to an individual having a home range in both breeding seasons. We defined the random effect "territory" as an animal having a home range in both years of the study. We used Akaike's Information Criterion (AIC_c) corrected for small sample sizes to select models that best described the data (Burnham and Anderson 2002). We considered models as competing models if they differed by ≤ 2 ΔAIC_c from the top model and used Akaike weights (w_i) as an indication of support for each model (Burnham and Anderson 2002). We used a two-sample *t*-test to determine if habitat variables within home ranges differed between years.

We assessed habitat selection by comparing use and availability of habitat types at the individual home-range level (design III; Manly et al. 2002). We used program R with the adehabitatHR library (Calenge 2011) to calculate selection ratios and chi-square tests for overall deviation from random use of habitat types. We defined "use" as the location of the animal during the time we located it using telemetry and "availability" as the amount of a specific habitat available to an animal within its home range (Manly et al. 2002). A positive or negative selection of a habitat was determined if the selection ratio (w) differed significantly from 1.0 (no overlap in 90% confidence intervals; Manly et al. 2002). Only locations at which we observed active foraging were included in resource selection analysis. We defined active foraging as an individual stooping from perch or flight, or flying or hovering close to the ground (Babcock 1995, Bechard et al. 2010).

We used known-fate analysis in Program MARK (White and Burnham 1999) with the logit-link function to evaluate adult survival rates during the breeding season. Due to sample size, we limited our survival analysis to three potential models to evaluate adult survival of breeding Swainson's Hawks: constant survival and models that included time (weekly) and year effects. We used Akaike's Information Criterion corrected for small sample size (AIC_c) to select models that best described the data (Burnham and Anderson 2002). We considered models as competitive if they differed by ≤ 2 ΔAIC_c from the top model and used Akaike weights (w_i) as an indication of support for each model (Burnham and Anderson 2002).

RESULTS

We captured and radio-tagged 15 adult Swainson's Hawks during the 2013 and 2014 breeding seasons. Captures occurred from 5 May to 10 June each year. In 2013, we captured and radio-tagged 13 adult Swainson's Hawks (six male and seven female). We collected locations on 10 breeding adults in 2013; three birds were censored from home-range analyses due to mortality ($n = 1$), radio malfunction ($n = 1$), and failure to breed ($n = 1$). In 2014, we captured and monitored two additional breeding adults (two males) and also monitored seven adults that were initially captured in 2013 and were monitored then. We collected 742 visually observed foraging locations that were used in home-range analyses; 433 in 2013 and 309 in 2014. Average number of locations per bird used to estimate home-range size was 43 (SD = 27). Average 95% MCP home-range size in 2013 was 205.4 ha (SD = 135.3 ha, $n = 10$) and 211.1 ha (SD = 208.8 ha, $n = 9$) in 2014, and sizes did not differ between years ($t_{13} = 0.07$, $P = 0.95$), averaging 208.3 ha (SD = 244.9 ha, $n = 19$ home ranges measured for 12 birds) for the duration of the study. Mean core home-range size (50% MCP) was 78.2 ha (SD = 105.9 ha, $n = 10$) in 2013 and 59.7 ha (SD = 80.7 ha, $n = 9$) in 2014. Core home ranges did not differ between years ($t_{17} = –0.46$, $P = 0.65$) and averaged 68.9 ha (SD = 131.6 ha, $n = 19$ home ranges measured for 12 birds) over the course of the study.

Table 2. The top ten ranked linear mixed-effects models used to determine the effect of land-cover variables on home-range size of breeding Swainson's Hawks in north-central South Dakota and south-central North Dakota, 2013–2014.

MODELS	K[a]	ΔAIC_c[b]	w_i[c]
Grass	2	0	0.47
Development	2	1.63	0.21
Grass + wetland + trees	4	2.73	0.12
Hay + grass + trees	4	3.65	0.08
Row crop + development	3	3.83	0.07
Wetland + trees	3	6.42	0.02
Row crop + hay	3	7.32	0.01
Trees	2	7.45	0.01
Row crop + graincrop + hay	4	8.07	0.01
Constant	1	8.24	0.01

[a] Number of parameters.

[b] Difference in AIC_c relative to the minimum AIC_c.

[c] Akaike weight (Burnham and Anderson 2002).

Linear mixed-effects models estimating the influence of land-cover type on home range size indicated that the model (Grass) was the top-ranked model ($w_i = 0.47$; Table 2); home-range size was positively associated with percent grass ($\beta = 5.12$, SE = 1.36, $P = 0.01$). Weight of evidence supporting this model was 2.24 times greater than the second-ranked model and 3.92 times $\geq$ the remaining models. The model (Development) also was a competitive model as it was ≤ 2 ΔAIC_c from our top-ranked model ($w_i = 0.21$; Table 2); home-range size was negatively associated with percent development ($\beta = –35.56$, SE = 10.49, $P = 0.02$). Swainson's Hawk home ranges increased 5.12 ha for every 1% increase in percent grass and decreased 35.56 ha for every 1% increase in percent development (Fig. 2). None of the remaining models were considered competitive (>2 ΔAIC_c; Table 2).

Of the 13 breeding Swainson's Hawks we initially captured in 2013, six did not return to the study area the following year. UDOI estimates for four of the seven birds who returned in 2014 exhibited an extremely high degree of overlap (UDOI $\geq$ 0.95; Table 3), whereas the three remaining birds

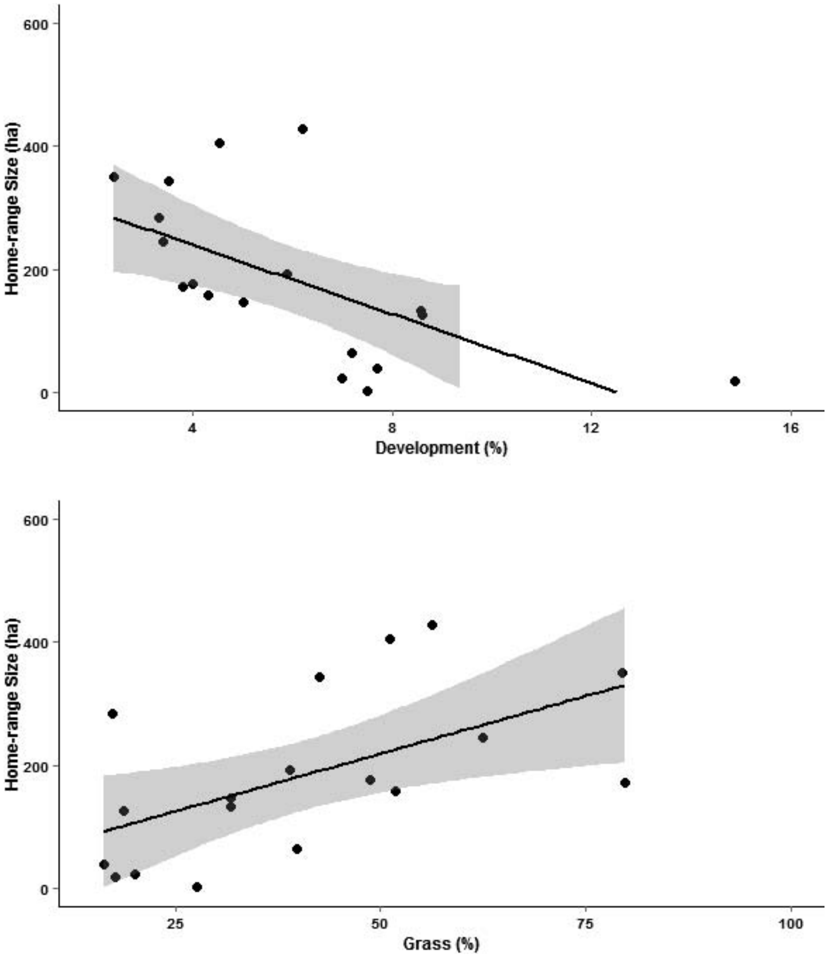

Figure 2. The relationship of percent development and percent grass on home-range sizes of breeding Swainson's Hawks in south-central North Dakota and north-central South Dakota, 2013–2014. 95% confidence limits are represented by the gray shaded area.

displayed a low degree of overlap (UDOI $\leq$ 0.29; Table 3). Average UDOI values for all seven birds indicated a moderately high degree of home-range overlap between years (UDOI = 0.69, SD = 0.45).

Swainson's Hawk home ranges in 2013 were made up primarily of grassland (44.0%), row crops (26.0%), and hay (13.9%; Table 4). Similarly in 2014, grassland (41.6%), row crops (28.9%), and hay (17.4%) accounted for the majority of land cover within home ranges (Table 4). Habitat within home ranges was similar between years ($t_{17} \leq 0.23$, $P \geq 0.26$), except for wetlands ($t_{10} = 2.55$, $P = 0.03$), which decreased within home ranges by 5.8% from 2013 to 2014.

Breeding Swainson's Hawks did not randomly select habitats for foraging based upon their availability in 2013 ($\chi^2_{42} = 781.99$, $P < 0.001$) and 2014 ($\chi^2_{40} > 999.99$, $P < 0.001$). In 2013, Swainson's Hawks selected trees ($w = 115$, 90% CI = 21.3–209) as perches for foraging more frequently than what was expected based on availability in their home range and selected wetland ($w = 0.06$, 90% CI = 0.00–0.17) and grassland ($w = 0.36$, 90% CI = 0.18–0.53; Table 5) habitats for foraging less than expected. In 2014, Swainson's Hawks selected grassland ($w = 0.47$, 90% CI = 0.35–0.60; Table 5) for foraging less than what was expected.

Table 3. Utilization distribution overlap index (UDOI) and home ranges for seven breeding Swainson's Hawks that occupied the same nest sites in 2013 and 2014.

	2013			2014			
BIRD ID	NO. OF LOCATIONS[a]	HR[b]	CORE HR[c]	NO. OF LOCATIONS[a]	HR[b]	CORE HR[c]	UDOI[d]
149.053	39	404.21	226.51	31	244.80	33.65	1.12[e]
149.254	40	171.69	7.20	33	642.78	237.22	0.23
149.272	42	284.53	15.77	35	19.28	0.16	0.29
149.312	47	299.49	157.07	35	192.21	49.46	0.95
149.333	42	3.47	0.03	31	39.74	3.38	0.15
149.365	46	344.20	62.29	39	175.77	55.72	1.17[e]
149.374	43	145.79	62.48	33	24.17	0.01	0.95

[a] Number of locations used to calculate home range.
[b] 95% MCP home range (ha).
[c] 50% MCP home range (ha).
[d] Indicates degree of overlap for home ranges; 0 (no overlap) and 1.00 (complete overlap; Fieberg and Kochanny 2005).
[e] UDOI >1 indicates two home ranges that are nonuniformly distributed on the landscape and are associated with a high degree of overlap (Fieberg and Kochanny 2005).

We were unable to determine the cause of death for the one bird that died four weeks after tagging. We also censored two individuals from survival analysis due to transmitter malfunction (bird was resighted three times during the season still wearing the malfunctioning transmitter at the nest location where she was observed prior to capture) and transmitter loss. The top model in our survival analysis was S_{Constant} ($w_i = 0.59$; Table 6) providing a survival estimate of 0.94 (95% CI = 0.68–0.99) for the duration of both breeding seasons combined. Our second competing model S_{Year} ($w_i = 0.40$; Table 6) indicating that survival varied between years.

DISCUSSION

Our results indicated that Swainson's Hawks in the northern Great Plains maintained substantially smaller home ranges than has been previously documented for the species in North America (e.g., Bechard 1982, Andersen 1995, Babcock 1995). Analysis of breeding-site fidelity indicated that Swainson's Hawks returning to our study area had a moderately high degree of home-range overlap and thus, used the same areas within home ranges each year. The analysis of the influence of land cover on home-range size indicated that percent grass and percent development had the largest influence on home-range size: larger home ranges with increasing grassland and smaller home ranges with increasing development. Our foraging habitat selection results indicated that Swainson's Hawks did not select habitats based upon their availability in both years of this study. Lastly, our results document high survival rates for adult Swainson's Hawks, which was similar to what has been previously documented (e.g., Briggs et al. 2011).

Previous studies examining home-range size of Swainson's Hawks have documented substantially larger breeding home ranges (Bechard 1982, Andersen 1995, Babcock 1995, Gerstell and Bednarz 1999) than those recorded during our study. In California, Swainson's Hawk home ranges were 2130 ha ($n = 6$; Andersen 1995), 4038 ha ($n = 4$; Babcock 1995), and 69–2884 ha ($n = 12$; Woodbridge 1991), whereas they were 866 ha ($n = 5$; Bechard 1982) and

Table 4. Land-cover variables (%; including mean and SD) measured within 100% MCP home ranges for breeding Swainson's Hawks in south-central North Dakota and north-central South Dakota, 2013–2014.

	2013 ($n = 10$)		2014 ($n = 9$)	
	% IN HOME RANGE		% IN HOME RANGE	
VARIABLE	$\bar{X}$	SD	$\bar{X}$	SD
Row crop	26.02	16.25	28.91	19.74
Grain crop	3.80	4.20	3.41	4.20
Hay	13.90	14.07	17.48	21.87
Grass	44.00	21.07	41.64	21.54
Wetlands	7.04*	6.61	1.24*	1.53
Trees	0.27	0.25	0.64	1.05
Development	5.00	3.78	6.67	3.48

* Significant difference between years ($P < 0.05$).

Table 5. Estimated selection ratios and confidence intervals for foraging adult Swainson's Hawks ($n = 19$) during the 2013 and 2014 breeding seasons in north-central South Dakota and south-central North Dakota, at the individual home-range level (Manly et al. 2002). The + symbol indicates that the selection coefficient (w) was significantly different from 1 and the habitat was used more than expected from the availability of this habitat. The – symbol indicates that the selection coefficient (w) was significantly different from 1 and the habitat was used less than expected from the availability of this habitat.

	2013			2014		
		90% CI			90% CI	
HABITAT	RATIO (w)	LOWER	UPPER	RATIO (w)	LOWER	UPPER
Row crop	0.72	0.30	1.13	0.67	0.15	1.19
Grain crop	1.41	0.07	2.75	1.97	0.00[a]	4.32
Hay	1.40	0.71	2.11	0.71	0.09	1.33
Grass	0.36^-	0.18	0.53	0.47^-	0.35	0.60
Wetland	0.06^-	0.00[a]	0.17	1.29	0.00[a]	3.78
Trees	115.23^+	21.29	209.17	50.42	0.00[a]	110.19
Development[a]	1.88	0.00[a]	3.77	1.07	0.00[a]	2.23

[a] Negative lower limit changed to 0.00.

980 ha ($n = 8$; Fitzner 1977) in Washington. Swainson's Hawks in New Mexico had home-range sizes more comparable to those in our study (400 ha, Gerstell and Bednarz 1999); however, home ranges for Swainson's Hawks in our study were only half the size of those in New Mexico, making them the smallest reported for breeding Swainson's Hawks, to our knowledge. However, as a caveat, we note that the small number of locations (Table 3) we used in our MCP estimates of home ranges might have resulted in an underestimation of home-range size.

Available habitats in previous studies provide evidence for the large variation in home-range size (e.g., Babcock 1995). In California, Babcock (1995) and Andersen (1995) found that tree fruit crops (nuts and citrus) dominated the landscape; therefore, Swainson's Hawks were required to fly long distances to find suitable foraging habitat (e.g., nearest alfalfa field). However, home ranges of Swainson's Hawks in our study area were made up of large proportions of foraging habitats (i.e., hay and grassland), likely contributing to substantially smaller home ranges than were documented in California (Babcock 1995). Agricultural production also composed a significant proportion of habitat within home ranges of Swainson's Hawks in our study. These results were similar to those of studies in Arizona (Nishida et al. 2013), Alberta, Canada (Schmutz 1987), and North Dakota (Gilmer and Stewart 1984), where Swainson's Hawks commonly nested in agriculturally rich landscapes.

The percentages of grass and development within home ranges had the greatest influence on home-range size of Swainson's Hawks in our study. Previous studies have suggested that home-range size of Swainson's Hawks was related to the availability of foraging habitat (Bechard 1982, Schmutz 1987, Preston 1990, Babcock 1995), which is likely a function of multiple factors such as prey density, vegetation height (e.g., prey accessibility), competition, and location of nest sites (Bechard et al. 1990, Restani 1991). Unlike Swainson's Hawks in California (Babcock 1995), Swainson's Hawks in our study were able to maintain small home ranges, likely due to the high availability of foraging habitat (e.g., wetlands, hay). Alternatively, the small home ranges may be due to Swainson's Hawks selecting farmsteads as nesting sites (Gilmer and Stewart 1984, Inselman et al. 2015). Our results indicated that as percent development increased, home-range sizes

Table 6. Survival models for radio-tagged adult Swainson's Hawks in south-central North Dakota and north-central South Dakota, 2013–2014.

MODEL	K^a	ΔAIC_c^b	w_i^c
$S_{Constant}$	1	0.00	0.59
S_{Year}	2	0.76	0.41
S_{Weekly}^d	15	25.18	0.00

[a] Number of parameters.

[b] Difference in AIC_c relative to the minimum AIC_c.

[c] Akaike weight (Burnham and Anderson 2002).

[d] Weekly = weekly survival during the breeding season.

decreased. Although the number of farms decreased 18% from 1980–2009 (United States Department of Agriculture 2010) in South and North Dakota, nest sites associated with farms may be valuable breeding territories for Swainson's Hawks because the farmsteads often provide mature nesting trees, as in North Dakota (Gilmer and Stewart 1984). Because Swainson's Hawks are less disturbed by human activity than some conspecifics (e.g., Ferruginous Hawks [*Buteo regalis*]); they are more likely to adapt and select this potentially high-quality habitat (Lokemoen and Duebbert 1976, Gilmer and Stewart 1984), which may provide them with the necessities for nesting in a small, localized area.

The roads in this landscape may also provide ideal foraging habitat for Swainson's Hawks. Ditches alongside roads provide favorable habitat for prey species (i.e., *Peromyscus* spp. and *Microtus* spp.), which may attract Swainson's Hawks to these areas for foraging. Likewise, frequent mowing of the areas along ditches may increase accessibility of prey that occur in high densities in roadside habitat (Schmutz 1987, Zelenak and Rotella 1997). Habitat selection for foraging by Swainson's Hawks in our study apparently was associated with prey accessibility, as in a study of Swainson's Hawks in Washington (Bechard 1982). Transmission line poles associated with roadways provide perch sites that also may improve foraging success of these birds in a landscape where tree perches are limited. Our results suggest that development (i.e., trees associated with farm sites) provides a resource (e.g., nest trees) that is limited in the prairie grassland ecosystem. Our results also indicate that small home-range sizes of Swainson's Hawks in the northern Great Plains may be related to the availability of foraging habitats.

Row crops, grain crops, and hay fields composed nearly half (44–50%) of the available habitat within home ranges each year. Swainson's Hawks used row crops proportionately; we observed that when vegetation reached heights that obscured the ground, birds then switched to more suitable habitats with shorter vegetation, such as harvested hay fields. Agricultural crop fields such as corn and soybeans may be used as foraging habitats during the early stages of nesting as frequent farming practices (e.g., plowing, planting) may expose prey. Also, frequently grazed pastures likely allowed accessibility to prey when hay and row crop vegetation was too tall for birds to effectively hunt. Swainson's Hawks did, however, select grassland habitats for foraging less frequently than predicted by its availability within home ranges in both years of the study. Swainson's Hawks likely shifted foraging strategies to other habitat types when grassland vegetation was too tall for effective foraging. We observed that Swainson's Hawks shifted foraging habitats almost exclusively to hay fields for the remainder of the study once hay harvesting began. Swainson's Hawks also utilized wetland habitats proportionally less than what was available in 2013. The small amount of wetland habitat available for foraging may be due to the loss of wetlands to agricultural practices, such as drain tile. Diets of Swainson's Hawks include wetland-dependent species in North Dakota and South Dakota (Murphy 2010, Inselman 2015); however, we recorded few foraging locations in wetland habitats in our study area. In 2013, we saw significant use of trees within Swainson's Hawk home ranges. This result is contrary to previous studies that suggested that Swainson's Hawks used perching habitats substantially less than other *Buteo* spp. (e.g., Red-tailed Hawks [*Buteo jamaicensis*]; Janes 1985, 1987). Janes (1985) also noted that Swainson's Hawks occupied habitats that contained few perches and foraged primarily from the air. The selection of trees within Swainson's Hawk home ranges in our study might be artificially high due to the lack of available trees in our study area, as total tree area accounted for less than 1% of available land cover. However, we frequently observed Swainson's Hawks hunting from power poles and trees, which may indicate that Swainson's Hawks use perches often in our region.

We documented a high degree of home-range overlap for four of seven breeding Swainson's Hawks that used the same nest sites in subsequent years. Interestingly, all three of the birds that returned to the same nest sites that exhibited a low degree of home-range overlap had suffered nest failures the previous year, which alone might lead us to link nest failure to a shift in breeding territory distribution and use. However, three of the four birds that exhibited a high degree of home-range overlap also had failed nest attempts in the first year of the study. This suggests that exact boundaries of breeding territories of Swainson's Hawks may be driven by other factors (e.g., foraging habitat, prey abundance, suitable nesting habitat) rather than the survival or failure of the nest in the previous year. Thus, Swainson's Hawks that occupy the same nesting territory regardless of nest survival may benefit from increased fitness by not having to search for new suitable habitat and potentially reduced competition for limited resources (e.g., nest sites; Inselman 2015, Inselman et al. 2015).

We documented high survival probabilities for breeding Swainson's Hawks in our study, similar to that found in California (0.85–0.90 [SE = 0.02]; Briggs et al. 2011) and western Canada (0.84 [SE = 0.019]; Schmutz et al. 2006). Apparent survival of Swainson's Hawks in California (Briggs et al. 2011) was negatively associated with reproductive success (e.g., number of offspring produced), while some extrinsic factors increased survival rates (e.g., presence of agriculture). Similarly, Schmutz et al. (2006) indicated that high adult survival was attributed to the ability of large raptors to withstand stress associated with biotic and abiotic factors. Due to our low sample size and lack of mortality during our study, we were unable to examine the effect of extrinsic and intrinsic variables on survival rates as was done by Schmutz et al. (2006) and Briggs et al. (2011). The survival estimates documented in our study may overestimate the true survival rates of this population due to the limited sample size of Swainson's Hawks tagged during this study or may underestimate survival estimates if they are extrapolated to an annual survival estimate. Therefore, caution should be used when interpreting our breeding-season survival results in the context of annual survival studies like those of Briggs et al. (2011) and Schmutz et al. (2006).

The small home ranges that we documented in this study are likely due to numerous factors (e.g., raptor density, available foraging habitat, nest sites). In a landscape of continuing grassland loss (1.0–5.4% annually; Wright and Wimberly 2013), Swainson's Hawks continue to establish home ranges in habitats of high grassland density. Small home ranges could suggest the availability of high quality habitat; however, concurrent research suggests a declining population (Inselman et al. 2015). Yet, as grass and shelterbelts are converted to corn/soybean production, the lack of available suitable nesting habitat may negatively affect Swainson's Hawk abundance in the northern Great Plains. This study provides baseline information useful when documenting the change in the spatial ecology of Swainson's Hawks as agriculture production becomes the dominant land cover in this landscape that was historically grassland.

ACKNOWLEDGMENTS

Our study was funded through the South Dakota Agricultural Experiment Station and through a State Wildlife Grant (T-36-R) administered through the North Dakota Game and Fish Department. The Nature Conservancy provided funding support for this work through the Nebraska Chapter's J.E. Weaver Competitive Grants Program. The U.S. Geological Survey provided analytical and technical support. We thank R. Johnson, E. Morata, T. Michels, S. Nevison, A. Kunkel, B. Schmoke, and E. Hoskins for their field assistance. We also thank all of the landowners in McPherson County, South Dakota, and Logan, McIntosh, and Dickey counties, North Dakota, who granted us access to their land. We thank M. Collopy for helpful comments on an earlier draft of this report. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Received 6 April 2015; accepted 17 May 2016
Associate Editor: Christopher W. Briggs