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ADULT HOME RANGE SIZE AND JUVENILE MOVEMENTS OF GRAY HAWKS IN THE LOWER RIO GRANDE VALLEY, TEXAS, USA

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ABSTRACT.—We studied the natural history of Gray Hawks (*Buteo plagiatus*) in the Lower Rio Grande Valley of Texas. We used GPS-GSM telemetry to quantify dispersal time and distance, winter home range size of juveniles, and home range size of adults. Home ranges were calculated using the kernel Brownian bridge home range estimator. The median dispersal date for 14 juvenile Gray Hawks was 11 August and they traveled a median straight-line distance of 453 km. Mean winter home range sizes for 11 juveniles was 707 ha. For juveniles, female winter home ranges were larger than those of males, and juvenile winter home ranges were larger in natural than in urban areas. Mean 95% home range sizes for 20 adult Gray Hawks was 530 ha. Mean adult male home range size was larger in natural than in urban areas. Adult Gray Hawks remained in their home ranges year-round.

KEY WORDS: *Gray Hawk*; Buteo plagiatus; *backpack harness*; *GPS-GSM transmitter*; *home range*; *juvenile movement*; *VHF transmitter*.

TAMAÑO DEL ÁREA DE CAMPEO DEL ADULTO Y MOVIMIENTOS DE JUVENILES DE *BUTEO PLAGIATUS* EN EL VALLE INFERIOR DEL RÍO GRANDE, TEXAS, EEUU

RESUMEN.—Estudiamos la historia natural de *Buteo plagiatus* en el Valle Inferior del Río Grande de Texas. Utilizamos telemetría GPS-GSM para cuantificar el tiempo y la distancia de dispersión, el tamaño del área de campeo de los juveniles en invierno y el tamaño del área de campeo de los adultos. Las áreas de campeo se calcularon utilizando el estimador de puentes brownianos del método kernel. La fecha mediana de dispersión de 14 juveniles de *B. plagiatus* fue el 11 de agosto y recorrieron una distancia mediana en línea recta de 453 km. El tamaño medio del área de campeo de invierno para 11 juveniles fue de 707 ha. Considerando los juveniles, las áreas de campeo de invierno de las hembras fueron más grandes que las de

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los machos, y las áreas de campeo de invierno de los juveniles fueron más grandes en las áreas naturales que en las urbanas. El tamaño medio del 95% del área de campeo para 22 adultos de *B. plagiatus* fue de 526 ha. El tamaño promedio del área de campeo de los machos adultos fue mayor en las áreas naturales que en las urbanas. Los adultos de *B. plagiatus* permanecieron en sus áreas de campeo durante todo el año.

[Traducción del equipo editorial]

INTRODUCTION

The Gray Hawk (*Buteo plagiatus*) is a small, Neotropical buteonine raptor whose range extends from the southwestern United States south to northern Costa Rica, including the Lower Rio Grande Valley (LRGV) of Texas (Sutton 1953, Brush 2005, Alderfer 2014). Once referred to as the Mexican Goshawk (Oberholser 1974), it was split from the Gray-lined Hawk (*Buteo nitidus*) by the American Ornithologists' Union in 2012 following a study by Millsap et al. (2011). Although fairly common in its Mexican and Central American range, there is little quantitative information about Gray Hawk population trends, habitat use, and ecology. Most of the literature addresses populations in Arizona, located in an arid temperate biome (Bibles 1999, Bibles et al. 2020, La Porte et al. 2020).

Generally thought to inhabit open riparian forest and edges of tropical and subtropical forests, Gray Hawks have not been regularly reported in urban areas (Brush 2005, Corman 2005, Boal 2018). In Texas, Gray Hawks have been recorded from the Trans-Pecos to the LRGV (Oberholser 1974), though they were seldom observed in the LRGV prior to 1925. Griscom and Crosby (1925) concluded the status of Gray Hawks could not be determined without further research and did not even list the species as accidental in the region. Davis (1955, 1966) listed the Gray Hawk as a rare winter visitor to the region, occurring in riparian habitat. As recently as 1974 the Gray Hawk was considered a former breeder in the LRGV, with rare winter sightings, limited almost exclusively to Bentsen-Rio Grande Valley State Park and Santa Ana National Wildlife Refuge (NWR) in Hidalgo County (Oberholser 1974, Gehlbach 1987).

In the late 1900s, Gray Hawks began to occur more regularly in the LRGV. The Texas Breeding Bird Atlas project located one confirmed Gray Hawk nest in the LRGV, during the 1987–1992 study period (Tweit 2007). McKinney (2002) considered Gray Hawks to be occasional with sightings year-round in the LRGV. Gray Hawks currently breed from Falcon Dam in Starr County to Santa Ana NWR in Hidalgo County (Brush 2005, Lockwood and Freeman 2014), with further expansion eastward evidenced by recent nesting records in Cameron County. Because of the small known nesting population, Gray Hawks are considered threatened in Texas (Texas Parks and Wildlife Department 2020).

Throughout most of its USA range, but not in the LRGV, the Gray Hawk is primarily migratory (Sutton 1953, Bibles et al. 2020). Some Gray Hawks in southern Arizona occupy the same territories year-round, though they have been observed defending these only during the breeding season (Bibles et al. 2020, La Porte et al. 2020). In Arizona, Gray Hawks typically return in late March or early April to the same nesting areas and either rebuild previous nests or construct a new nest nearby (Corman 2005, Bibles et al. 2020). Little is known about the Gray Hawks' winter range outside the USA (Bibles et al. 2020), and no studies have attempted to determine if breeding pairs maintain pair bonds and home ranges year-round in the LRGV. The LRGV is situated in the subtropical biome, with less seasonality in resources than in arid parts of Arizona, which may favor flexible migratory and dispersal strategies by Gray Hawks within the LRGV.

Knowledge of Gray Hawk habitat use remains mostly anecdotal. Although typically described as occurring in natural habitat, some past publications have mentioned use of human-influenced habitats (Bibles et al. 2020). The Gray Hawk occasionally nests near houses (Dunne 2006, Bibles et al. 2020). In the LRGV in 2014, a pair of Gray Hawks nested in a park in southern Hidalgo County that was heavily used by people on weekends, but adjacent to large tracts of natural habitat (T. Brush and W. Clark unpubl. data). Boal (2018) listed the Gray Hawk as a species that may possibly utilize urban areas in the summer. Recently, in the cities of Harlingen, Mercedes, Pharr, McAllen, and Edinburg, Texas, Gray Hawks have nested in residential yards (T. Brush and W. Clark unpubl. data), which suggests that the status of Gray Hawks in urban areas needs further study, especially given the growth of urban areas and limited amount of suitable natural habitat.

In general, raptors are particularly sensitive to habitat loss and fragmentation (Glinski 1986,

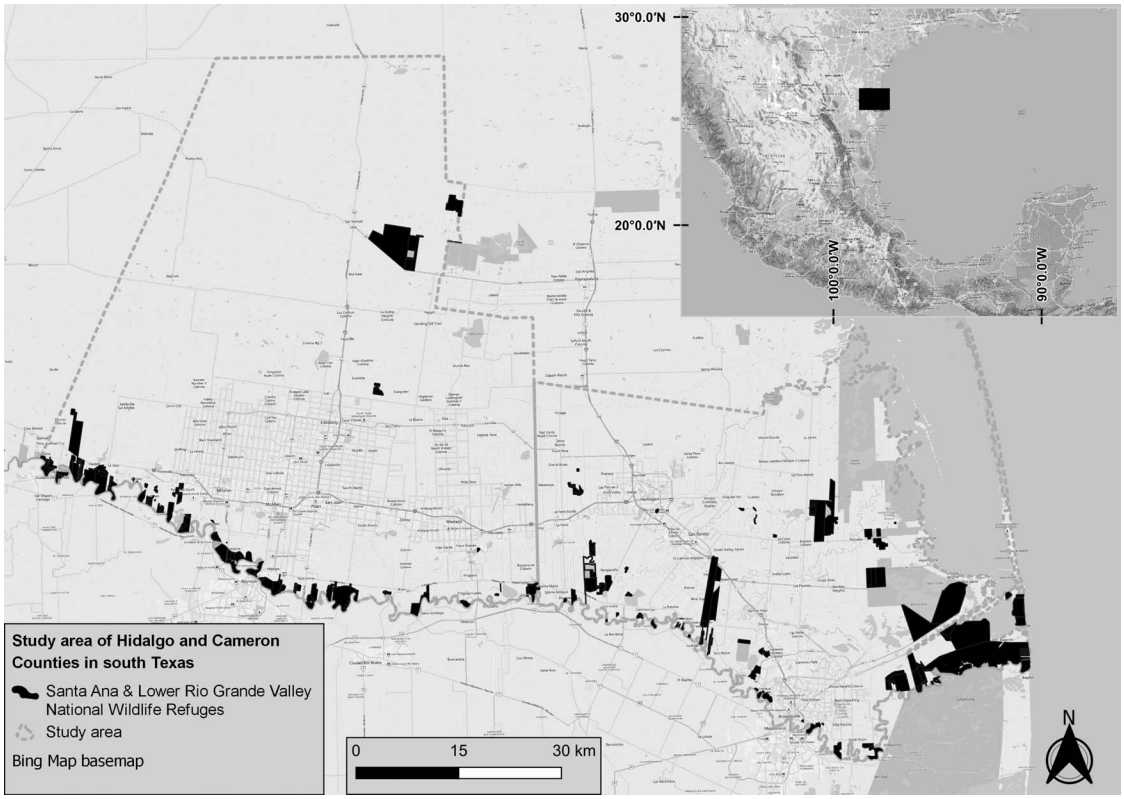

Figure 1. Map showing the study area of Cameron and Hidalgo Counties in the Lower Rio Grande Valley in south Texas.

Whaley 1986, Cruz et al. 2021) and the LRGV has very little native habitat remaining (US Fish and Wildlife Service 2013); thus, a better understanding of the Gray Hawks' breeding and nonbreeding home ranges in south Texas will help protect their populations (Carrete et al. 2009, Brown et al. 2014). This study focused on two aspects (juvenile movement and adult home ranges) of Gray Hawk biology in the study area of Hidalgo and Cameron Counties in the LRGV (Fig. 1), a subtropical biome with less extreme variation in year-round resources than other portions of their USA range. Through observation of color-banded and transmittered individuals, we determined when fledglings departed the post-fledging family area, defined as the area used from the time the young fledged until they were no longer dependent on the adults for food (Tapia et al. 2007), and how far they travelled after dispersing. In addition, the use of GPS-GSM transmitters (subsequently referred to a GSM transmitters) allowed us to determine home range sizes of adult Gray Hawks in the LRGV.

Methods

Data Collection. This study was conducted from December 2019 to August 2021. We were aware of 11 previous Gray Hawk nesting locations, six in natural areas and five in urban areas, and we searched for additional nest sites (a nest structure built or attended by Gray Hawks and the surrounding immediate area used by the breeding pair) within the study area early in the breeding season. Occupied territories were defined as any defended area (Steenhof and Newton 2007). A nest site was considered occupied if we observed a pair and they displayed behavior such as territorial vocalizations or courtship display flights associated with nesting activities, if it contained a nest (a platform of sticks) and attending pair, if there was a pair defending a new or refurbished nest, or if we observed a food delivery to a nest (Bibles and Mannan 2004, Stout et al. 2007). Stensrude (1965) observed a pair of Gray Hawks in Arizona over a 3-mo period from late February to late May and found the birds were most

active around 0800–0900 H, so we focused our attempts at locating occupied nests sites during those hours, though we also searched at other times of day during the breeding season.

Nest checks were not performed while the nest contained eggs or nestlings younger than 2 wk old, to reduce the risk of nest desertion (Bloom 1974). If nest height allowed, we performed checks using a wireless cavity inspection camera (www.ibwo.org) and a 15-m fiberglass Crain measuring rod. Before inspecting or climbing to a nest, we ensured our presence was known to reduce the risk of a startled parent trampling eggs or young (Fyfe and Olendorff 1976).

When possible, we climbed nest trees to band nestlings ≤2 wk prior to the normal fledging age of 42 d (Bibles and Mannan 2004). Banding at nests occurred prior to noon, to ensure young were not exposed to excessive heat (Fyfe and Olendorff 1976). Nestlings were lowered to the ground for increased safety during the banding process (Hull and Bloom 2001).

Forty-four Gray Hawks were fitted with 10-g or 12-g GPS transmitters that used the local cellular communications network (OrniTrack 10 or E10 solar-powered GPS-GSM/GPRS/3G, Ornitela, UAB, Vilnius, Lithuania; www.ornitela.com), or a 13-g VHF transmitter (Raptor AWE-R-13, American Wildlife Enterprises, Monticello, FL, USA). We allotted 15 of the GSM transmitters for adults and 14 for juveniles to obtain nearly equal representation of juvenile and adult age classes in our sample. We trapped juveniles for transmitter attachment after they had fledged to ensure proper fit of the attachment. No preference was given to sex of either adults or juveniles but, when selecting fledged juveniles, we preferably chose birds that had been previously banded as nestlings. The 15 VHF transmitters were reserved for adults, again with no preference given to sex. To ensure birds were not negatively impacted by additional weight, we adhered to the standard practice of applying only tags weighing <3% of the bird's body mass (Kenward 2001).

We fit backpack-type harnesses to adults and fledglings because they can be used to track birds over multiple years (Walls and Kenward 2007). We initially constructed the harnesses using natural tubular Teflon tape (Bally Ribbon Mills, Bally, PA, USA), later switching to natural tubular Spectra tape, also from Bally Ribbon Mills (Kenward 2001, Stewart and Millsap 2022).

To capture Gray Hawks, we used bal-chatri or phai traps, a bow net, or mist nets with a mounted Great Horned Owl (*Bubo virginianus*) lure near the nest sites (Bloom et al. 2007). To minimize risk of desertion of nests, we did not trap hawks during incubation. We banded each bird with one band on each leg, a numbered US Geological Survey (USGS) aluminum band and a color band (Acraft Sign & Nameplate Co. Ltd., Edmonton, Alberta, Canada). Male Gray Hawks received a black size 6 color band on their right leg, and females an orange size 7A band on their left leg (Varland et al. 2007). We chose black and orange to ensure the colors would be easy to distinguish from each other (Howitz 1981, Varland et al. 2007). We publicized the color-banding aspect of this project at least once every 3 mo at local parks and through other means to promote a similar resighting probability throughout the duration of the study (Varland et al. 2007).

We used size to determine the sex of Gray Hawks; for adults and fledglings, we recorded the mass, wing chord, and culmen from cere length, but we recorded only mass for nestlings (Hull and Bloom 2001, Pyle 2008). Females are approximately 10% larger than males with no overlap in mass of adult birds (Bibles et al. 2020). This size difference was used to estimate the sex of nestlings (Olendorff 1972). Birds were classified as either juvenile, in their first basic plumage, or adult, in their definitive basic plumage (Clark and Pyle 2015). We included every nest that we found within Cameron and Hidalgo Counties in the sample and attempted to trap every Gray Hawk located. The area fledglings used while still dependent on adults for food was defined as the post-fledging area (Harrower et al. 2010).

For hawks mounted with VHF transmitters, we recorded whether each bird was present or absent during the winter in each applicable home range using a folding 3-element Yagi antenna and R-1000 telemetry receiver (Communications Specialists, Inc., CA, USA). We used the VHF transmitters in addition to color band resightings and GPS-GSM transmitters to determine whether hawks remained in their home range year-round. We attempted to locate hawks with VHF transmitters at least twice per month from November through January, and at varying times of day (Walls and Kenward 2007). We also used VHF transmitters to locate nesting females, but they were not used for home range calculations.

Analyses. We determined adult home range size by year and juvenile home range size during winter

using the estimation of kernel Brownian bridge home range (BBHR; Horne et al. 2007). The estimation of BBHR is the most appropriate method for this dataset due to the very large number of GPS fixes obtained and the relatively short time span between fixes. Most GSM transmitter fixes were 30 min apart, with some as frequent as 15 min and some 8 hr apart; frequency of fixes depended on the battery charge of the transmitter. Fixes located close in time are likely autocorrelated and cannot be considered independent from one another; however, the BBHR method addresses this issue by assuming the fixes are not independent and incorporates the time between fixes directly into the model when calculating home range size (Horne et al. 2007).

We determined 20%, 50%, and 95% contours to assess where the birds spent 20% of their time, a 50% core area, and the outer 95% extent of their home ranges, respectively (Moss et al. 2014). For females tracked throughout the breeding season, we excluded GPS fixes obtained from 7 April to 15 June to ensure time spent at nest locations would not influence the home range size. Two adult males we presumed were unmated males were never observed with another Gray Hawk and their greater variability in GPS fixes suggested they were making regular forays in search of a mate. Based on their behavior, we excluded these from analyses. We performed all home range analysis using R 4.0.3 and the CRAN package *adehabitatHR* 0.4.19. We used QGIS 3.14.15-Pi for spatial analysis and mapping.

We grouped home ranges into two very basic classifications, natural or urban, to allow for some comparison between adult home ranges; future research will examine Gray Hawk habitat selection in the LRGV. We classified a home range as urban if it was inside a town or city, had extensive human modifications, and the 95% BBHR home range contained homes or commercial structures with more than 50% of a bird's GPS fixes within 100 m of these structures. Natural areas were those with natural vegetation and no houses, buildings, development, or other human disturbance, though these areas may contain roads. We compared adult home range sizes at the 20%, 50%, and 95% contours for males and females and between land cover types using two-way ANOVAs with interaction in a Bayesian framework (model 10.5.2 in Kéry 2010). We had insufficient sample sizes for some sex and land cover combination analyses. We also compared juvenile 95% BBHR between land cover types using a one-way ANOVA. We assumed lognormal distributions for home range sizes, and used uninformative priors (Normal [0, 0.001] for means, Uniform [0, 100] for standard deviations). For each analysis we computed three chains with 50,000 iterations each, the first 5000 of which were discarded as burn-in, and with a thinning rate of 5, yielding 13,500 samples from the posterior for each parameter. We assumed models converged if $\hat{R} < 1$ (Gelman and Hill 2007) and effective sample sizes were >10,000 (model code and output are in Supplemental Material S2). We computed the probability (*Pr*) that mean parameter estimates differed by subtracting the posterior samples; we report the proportion of the differences that were of the same sign as the mean and considered $Pr > 0.90$ as significant. Finally, we ran Pearson's product-moment correlation test in R to determine if there was a correlation between the number of GPS fixes and the sizes of adult home ranges and juvenile winter home ranges as a check to determine whether home range sizes increased as the number of GPS fixes increased.

We defined dispersal as the date a juvenile moved >1 km from its natal nest without returning for the next 5 d. Straight-line distance travelled was defined as the distance from the nest coordinates to the center of the 50% BBHR winter home ranges. Beginning of spring movement was defined as the date juveniles first moved >5 km from the boundary of their winter home ranges. We defined these based on our combined observations of the juvenile movements throughout the year. Because small sample sizes of juveniles with GSM transmitters precluded the assumption of normally distributed data and visual inspection showed the data were right-skewed, we compared straight-line distance travelled using the Wilcoxon rank sum exact test with an alpha level of 0.10.

Results

During this study, we color-banded 112 Gray Hawks: 62 males and 50 females. We deployed 15 VHF transmitters on adults, four on males and 11 on females. We deployed all 29 GSM transmitters; seven of these were recovered from dead hawks and hawks that chewed through their harnesses and subsequently redeployed on other Gray Hawks, and five were lost. Overall, eight juvenile males, 16 adult males, six juvenile females, and six adult females were tracked via GSM transmitters. Over the duration of the study, we found 54 territories with Gray Hawks, 50 of which were occupied by a pair of

Table 1. Home range sizes of 20 adult Gray Hawks, showing 20%, 50%, and 95% contours for adult Gray Hawks. Range sizes estimated with the kernel Brownian bridge home range estimator. Males are identified by a black color band and two-digit code and females by an orange color band with a two-character alphanumeric code. Also shown are the total number of days the bird was tracked plus the total number of fixes obtained, and a classification of whether the home range was in a natural or urban area based on land cover type. Distances less than 10 km are reported to one decimal place for increased resolution of smaller areas.

Bird ID	Land Cover Type	Number of GPS Fixes	Number of Days Tracked	Area Used (Brownian Bridge Movement Method)		
				20% (ha)	50% (ha)	95% (ha)
Black 03	Urban	500	14	2.8	15	117
Black 04	Urban	1143	65	5.4	23	167
Black 06	Natural	6225	350	5.3	24	238
Black 07	Natural	16,443	524	9.4	46	574
Black 08	Natural	2739	97	21	93	1941
Black 09	Natural	10,095	330	3.8	14	93
Black 11	Natural	3618	101	6.6	30	281
Black 12	Natural	2196	107	10	35	326
Black 13	Natural	12,539	488	9.0	54	587
Black 14	Urban	12,368	451	3.8	19	330
Black 29	Natural	11,133	404	12	49	613
Black 31	Natural	4821	368	13	70	706
Black 32	Natural	8867	360	9.1	51	760
Black 36	Natural	6355	331	17	114	1083
Orange 0D	Natural	287	32	7.5	28	166
Orange 0H	Urban	2678	401	12	52	1355
Orange 0K	Urban	229	18	2.0	8.8	69
Orange 0P	Urban	5094	526	7.1	40	573
Orange 0S	Urban	444	25	1.3	5.0	66
Orange 1W	Urban	4318	287	1.8	9.1	80
Mean		**5605**	**265**	**8.0**	**39**	**530**
SD		**4802**	**185**	**5.2**	**28**	**479**

Gray Hawks and four were inhabited by single birds; 24 of these were in urban areas.

Adult Home Ranges. The 95% BBHR mean annual home range sizes for adult Gray Hawks was 530 ha (SD = 479, $n = 20$) and ranged from 66 to 1941 ha (Table 1). The mean home range for males was 558 ha (SD = 27, $n = 14$) while for females it was 465 ha (SD = 41, $n = 6$). Gray Hawks in natural areas (mean = 614 ha, SD = 29, $n = 12$) had home ranges that averaged larger than those in urban areas (mean = 404 ha, SD = 35, $n = 8$; Pr (natural > urban) = 1.0).

Mean 95% home range size for males in natural areas was 529 ha (SD = 192), compared to 234 ha (SD = 207) in urban areas (Pr (natural > urban) = 0.91). Mean 95% home range size of females in urban areas was 252 ha (SD = 142), similar to that of males (Pr(male > female) = 0.59). The 95% home range for the only female in a natural area was 166 ha. The Pearson's product-moment test for correlation between the number of GPS fixes and the 95% BBHR home range sizes was positive and statistically not significant ($r = 0.28$, $P = 0.20$).

Juvenile Movement. The median dispersal date for the 14 juveniles tracked was 11 August 2020 (range = 1 August to 9 September). Locations of winter home ranges varied widely with most juveniles wintering in the LRGV, but three (two males, one female) undertook longer-distance movements to Central America (Table 2; Supplemental Material Fig. S1).

The 14 juveniles (eight males, six females) with GSM transmitters included three sets of siblings (two male siblings, two female siblings, and a mix of sexes). The two male siblings dispersed within 2 d of each other and travelled mainly within the study area, both wintering relatively close to their post-fledging family areas. A set of three siblings stayed within or close to the study area with two of the siblings, the male and one female, wintering within 2 km of their nest site. Two females from a nest in Harlingen,

Table 2. Juvenile Gray Hawk dispersal dates and distances travelled. Dispersal dates of eight juvenile males (black bands) and six juvenile females (orange bands), with the dates they settled on a winter home range in 2020, and the dates they began moving in the spring of 2021. Distances travelled are the distance in kilometers from the nest tree to the center of the winter home range. Transmitters of three juvenile males, Black 17, Black 19, and Black 21, stopped transmitting prior to the first winter. Distances less than 10 km are reported to one decimal place for increased resolution of smaller movements.

Bird ID	Date Dispersed (2020)	Date Stopped for Winter (2020)	Straight-line distance (km)	Date Started Moving in Spring (2021)
Black 17	19 August	NA	NA	NA
Black 19	12 August	NA	1906	NA
Black 20	1 August	18 November	0.6	18 March
Black 21	2 August	NA	1773	NA
Black 22	11 August	21 November	3.3	20 April
Black 23	9 August	30 November	5.2	11 April
Black 30	10 August	13 November	7.0	24 March
Black 34	9 September	24 December	15	20 March
Orange 0Z	3 August	1 November	12	20 March
Orange 1A	5 August	7 November	1.1	3 March
Orange 1E	26 August	22 December	34	15 March
Orange 1H	23 August	11 November	45	23 February
Orange 1K	17 August	19 November	1644	27 March
Orange 1N	6 August	16 December	437	5 April

Texas, differed greatly: one wintered in Brownsville, Texas, and the other travelled to El Salvador.

Two juvenile males travelled to Central America where their transmitters stopped transmitting, one in Nicaragua and the other in Honduras. We presume both died, though it is possible that they travelled to areas with no cellular coverage and remained there, or that the transmitters permanently failed. The transmitter of another male stopped transmitting around 2 October 2020, in Cameron County, Texas, with the last GPS fix over a pond, and he was presumed dead. All three abruptly stopped transmitting, giving no indication what may have happened, and none settled on winter home ranges, but we did include the two that travelled to Central America in the analysis of winter movements using the straight-line distance from the nest coordinates to the last GPS fix obtained.

The average date juveniles settled on a winter home range was 25 November 2020 (median = 19 November, range = 1 November to 24 December, n = 11). Nine of the 11 juveniles settled for the winter in urban areas; the other two were in natural areas in Tamaulipas, Mexico, just south of Santa Ana NWR and relatively close to the international border. Six juveniles completely left the USA for the winter. In addition to the two males whose transmitters stopped transmitting after reaching Central America, one female spent the winter in Tampico, Tamaulipas, Mexico, and another female wintered in El Salvador. The three that moved to Central America departed the USA in late October (21, 27, 28 October), with the female that travelled to Tampico not departing until 3 December.

The three Gray Hawks that travelled to Central America followed very similar routes (Fig. 2). The female that wintered in Mexico returned 6 April 2021, and the female from El Salvador returned 14 April. Of the four hawks that moved long distances, three were from nests in urban areas. The fourth bird was a male from a nest in a natural area near Santa Ana NWR.

The 95% BBHR winter home range sizes for juvenile Gray Hawks ranged from 132–2509 ha (Table 3). Sample sizes did not allow for comparison of home ranges in the natural land cover type by sex, but in urban areas the mean 95% BBHR for females (mean = 770 ha, SD = 44) was larger than for males (mean = 547 ha, SD = 50; Pr(female > male) = 0.99). We pooled home ranges for males and females and compared 95% BBHR between land cover types; the mean home range in the natural land cover type (872 ha, SD = 68) was greater than in the urban type (671 ha, SD = 33; Pr(natural > urban) = 0.99). The Pearson's product-moment test for correlation between the number of GPS fixes and the 95%

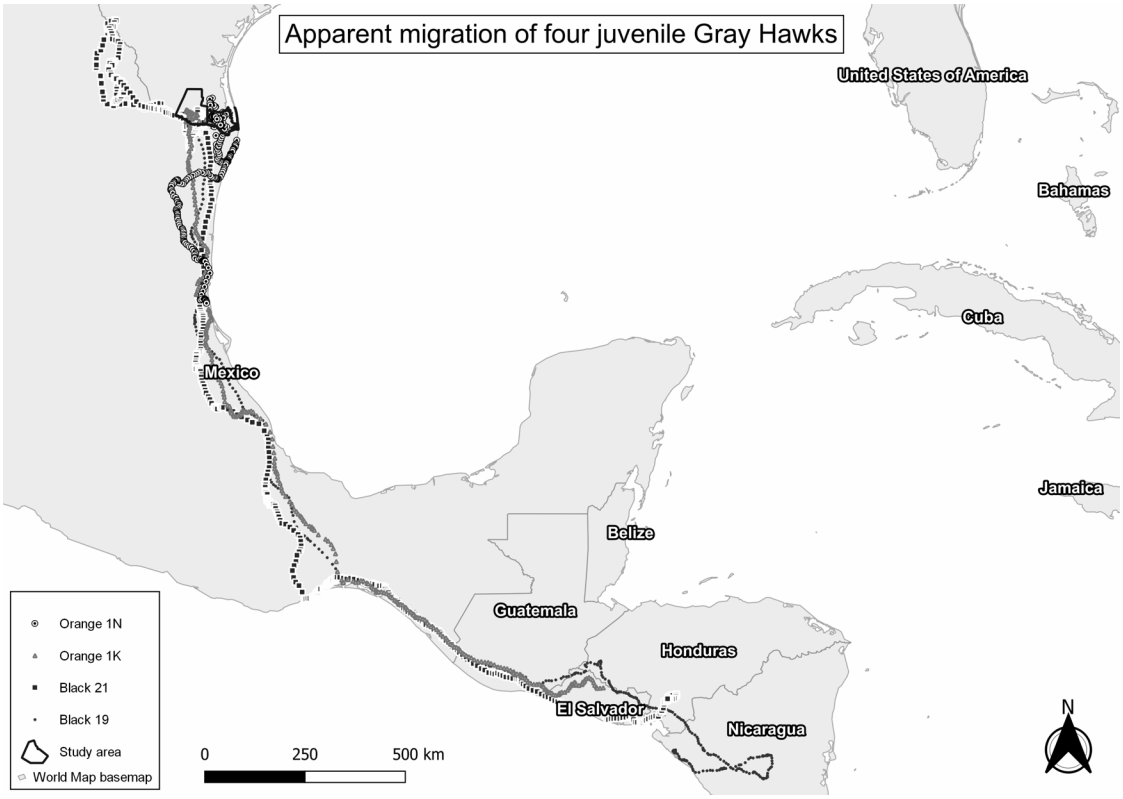

Figure 2. Map showing apparent migration of four juveniles that left the study area, with two females travelling to Mexico and El Salvador and two males travelling to Nicaragua and Honduras.

BBHR winter home range sizes was positive but not statistically significant ($r = 0.18$, $P = 0.60$).

The average date juveniles departed their winter home ranges in the spring of 2021 was 23 March (median = 20 March, range = 23 February to 20 April). Of the 11 juveniles, none settled in a nesting territory and attempted to breed in their second calendar year. They moved throughout the study area; most did not stay in an area for more than a few days. Several hawks returned to their winter home range before continuing to roam the LRGV. Three Gray Hawk home ranges within the study area contained adult males paired with juvenile females; these females did not lay eggs in the spring of 2021.

DISCUSSION

Our objectives for this study were to determine when fledglings departed their post-fledging family area and how far they travelled from their nest sites, and to determine home range sizes of adult Gray Hawks in the study area. By determining juveniles' dispersal dates and distances travelled we have filled a knowledge gap in the life history of Gray Hawks. To our knowledge, home range sizes have been documented in only one study, and this was for birds in Arizona (Bibles 1999). We have documented new information about the Gray Hawk population in Texas, which is state-listed as threatened (Texas Parks and Wildlife Department 2020).

The LRGV is one of the fastest growing regions of the USA and urban sprawl can have important implications for species with inflexible foraging strategies and resource differences between their native habitat and urban areas. Gray Hawks in areas we classified as natural had larger home range sizes than those in urban areas, which could be due to less available habitat for them to occupy in these urban areas or differences in foraging efficiency or prey abundance. It is possible hawks in urban areas may require less space because of more abundant prey due to human activity (Millsap 2017). Future research should compare the diets of Gray Hawks

Table 3. Winter territory sizes of 11 juvenile Gray Hawks, showing 20%, 50%, and 95% contours for juvenile Gray Hawks on their winter ranges. Range sizes estimated with the kernel Brownian bridge home range estimator. Males are identified by a black color band and two-digit code and females by an orange color band with a two-character alphanumeric code. Also shown are the total number of days the bird was tracked plus the total number of fixes obtained, and a classification of whether the home range was in a natural or urban area based on land cover type. Distances less than 10 km are reported to one decimal place for increased resolution of smaller areas.

Bird ID	Land Cover Type	Number of GPS Fixes	Number of Days Tracked	Area Used (Brownian Bridge Movement Method)		
				20% (ha)	50% (ha)	95% (ha)
Black 20	Urban	1399	119	8.8	44	447
Black 22	Urban	6170	149	12	67	879
Black 23	Urban	5457	132	6.9	32	310
Black 30	Natural	4915	130	12	68	503
Black 34	Urban	3928	85	13	70	553
Orange 0Z	Urban	2818	139	14	58	507
Orange 1A	Urban	1187	115	12	57	546
Orange 1E	Natural	2613	83	12	100	1241
Orange 1H	Urban	1062	104	4.0	19	132
Orange 1K	Urban	1960	127	5.5	19	155
Orange 1N	Urban	705	109	48	240	2509
Mean		**2929**	**118**	**13**	**70**	**707**
SD		**1916**	**21**	**12**	**61**	**675**

in urban and natural areas to determine what, if any, differences exist in prey abundance and prey species consumed, as well as research to analyze specific habitat requirements and population demographics within the LRGV. This additional information, along with knowledge gained during this study, will help inform and guide future conservation efforts.

Adult Gray Hawks in the LRGV study area did not migrate. All adults tracked via GSM or VHF remained in their home ranges year-round with the pairs remaining together. Two males were never seen with another Gray Hawk and were believed to be unmated, though this could not be confirmed. These two made numerous long-distance forays that skewed the male home range size estimates. Removing these two males reduced the mean home range size for males, shrinking the difference between sexes, with home range size for males nearly 20% larger than for females.

Our results provide strong evidence that pairs maintained their pair bond in the same home range year-round. Of the 15 adult Gray Hawks with VHF transmitters, all were paired with another adult, and the VHF signal could be detected from the capture location year-round. Only one hawk, an adult female, was difficult to locate during the winter, as she could not always be detected from where she was captured. This female spent some time during the winter across the Rio Grande in Mexico. During one site visit, this individual was located approximately 2.3 km from where she was captured near Anzalduas County Park in Hidalgo County, at a location where she nested in the spring of 2021. Three of the adults with VHF transmitters were paired with an adult wearing a GSM transmitter.

Overall, landscape type appeared to influence home range size more than sex. In the urban area, where our sample had adequate numbers of both sexes to test, the probability the mean home range differed between the sexes was approximately 0.59 (results of Bayesian analyses included in the R Markdown file in Supplemental Material S2).

Four of the juvenile Gray Hawks wintered well outside of the study area, three of them in Central America. For the three juveniles that travelled to Central America, departure dates coincided with the timing of fall migration for Gray Hawks in Arizona (Corman 2005). This suggests some Gray Hawks within the LRGV may be migratory; this deserves further study.

Considering the tremendous amount of habitat loss and fragmentation throughout the LRGV (US Fish and Wildlife Service 2013), the fact that we found Gray Hawks widespread and more numerous than prior accounts was unexpected. We attribute part of this unexpected outcome to the Gray Hawk's

flexibility in the use of urban areas. Of the 50 pairs of Gray Hawks located within the study area, 21 pairs were confirmed breeders in one or both years. The total number of Gray Hawks located during this study suggests the total USA population of Gray Hawks is larger than previously estimated (Kaufman 1996, Alderfer 2014, Bibles et al. 2020). The main population in Texas appears to be in Cameron and Hidalgo Counties within the LRGV. It remains to be determined whether breeding also occurs in the remaining counties of the LRGV, and upriver to the Laredo and Del Rio areas, given the regular occurrence of birds there.

SUPPLEMENTAL MATERIAL (available online). Figure S1: Maps showing dispersal patterns of 14 juveniles. S2: Gray Hawk home range analysis.

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