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Home Range Dynamics and Juvenile Dispersal of Gray Hawks in the Lower Rio Grande Valley

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HOME RANGE DYNAMICS AND JUVENILE
DISPERSAL OF GRAY HAWKS IN THE
LOWER RIO GRANDE VALLEY

A Thesis

by

MICHAEL STEWART

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ABSTRACT

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I studied the natural history of Gray Hawks (*Buteo plagiatus*) in the Lower Rio Grande Valley of Texas. I used radiotelemetry to quantify dispersal time and distance, winter territory size of juveniles, and home range size of adults. Home ranges were calculated using the minimum convex polygon, kernel home-range, and kernel Brownian bridge home range estimators. The median dispersal date for 14 juvenile Gray Hawks was August 11 and they traveled a median straight-line distance of 453 km. Median 95% BB home range sizes for 22 adult Gray Hawks was 452 ha and for 11 juveniles' winter territories the median was 507 ha. Adults home range sizes differed by sex and by habitat, juvenile winter territory size did not differ by sex or by habitat. Adult Gray Hawks remained in their territories year-round.

This information will help guide conservation efforts for Gray Hawks in Texas where they are threatened.

DEDICATION

The completion of my research project would not have been possible without the love and support of my family. My mother, Dr. Sherry Stewart, my father, Tom Stewart, and my wife, Yvette, inspired and motivated me to accomplish this degree after retiring from the U.S. Army. Thank you for your love and support. Additionally, there is no way I could have completed this research without the mentorship and expertise provided by William S. Clark.

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I would also like to thank Acraft Sign & Nameplate Co. Ltd., Bally Ribbon Mills, Communications Specialists Inc., American Wildlife Enterprises, and Ornitela, UAB; these companies had no influence on my study design, results, analyses, or conclusions. I thank the U.S. Fish and Wildlife Service, Texas Parks and Wildlife Department, The Nature Conservancy, the National Butterfly Center, the Gorgas Science Foundation, and numerous private landowners for providing access to sites throughout the Lower Rio Grande Valley. This research was conducted in compliance with the Guidelines to the Use of Wild Birds in Research. The Institutional Animal Care and Use Committee at The University of Texas Rio Grande Valley approved this study (AUP-19-41). Gray Hawk banding and auxiliary marking was conducted under Federal Bird Banding Permit 09289 and Texas Scientific Permit SPR-0702-226, and possession of the taxidermied Great Horned Owl was authorized under Federal Scientific Collecting Permit MB81980D-0 and Texas Scientific Permit SPR-0220-024.

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CHAPTER I

INTRODUCTION

The Gray Hawk (*Buteo plagiatus*) is a small, neotropical buteonine raptor resident year-round from the southwestern United States south to northern Costa Rica; its generally lowland range includes 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 (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.

Generally thought to inhabit open riparian forest and edges of tropical and subtropical forests, Gray Hawks have not been reported regularly in urban areas (Brush 2005, Corman 2005, Boal 2018). This species has a varied diet, in which snakes, lizards, and small mammals are the main food items consumed, but also birds, amphibians, and invertebrates (La Porte et al. 2020). Morphometric evidence shows a greater difference in diet may exist between the sexes in the northern populations (Millsap 1986). Most of the literature addresses populations in Arizona, located in an arid temperate biome (Bibles 1999, Bibles et al. 2002, La Porte et al. 2020).

Gray Hawks have never been common or widespread in the United States and their range and seasonal status have been poorly understood. In the early 20th century, Gray Hawks were fairly common locally in riparian forests in southeastern Arizona. By the 1960s, the Arizona distribution had shrunk, due to habitat deterioration (Phillips et al. 1964). By the late 1990s, some range expansion had occurred in southeastern Arizona (Corman 2005), possibly due to both increased field effort and protection of additional riparian habitat. Because of their expanding population Gray Hawk is no longer considered a Species of Greatest Conservation Need in Arizona (K. Jacobson, personal communication). In New Mexico, Gray Hawks have not been a regularly occurring species for long. In 1876, Frank Stephens collected two sets of eggs in New Mexico and subsequently identified them as Gray Hawk eggs, but Hubbard (1974) concluded the eggs instead belonged to Cooper's Hawks (*Accipiter cooperii*). There were credible observations of Gray Hawks in New Mexico in 1975, and in the early 1990s a suspected breeding pair was observed. By 2000, Gray Hawks were being seen there annually at multiple sites, mainly in southern New Mexico (Williams and Krueper 2008).

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. Davis (1955, 1966) listed the Gray Hawk as a rare winter visitor, 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 east evidenced by recent nesting records in Cameron County (W. S. Clark, personal communication). Given the small known nesting population, Gray Hawks are considered threatened in Texas (Texas Parks and Wildlife Department, 2020).

Throughout most of its U.S. range, but not in the LRGV, the Gray Hawk is essentially migratory (Sutton 1953, Bibles et al. 2002). 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. 2002, La Porte et al. 2020). In Arizona, Gray Hawks typically return in April or early May to the same nesting areas and either rebuild previous nests or construct a new nest nearby (Corman 2005). Little is known about the Gray Hawks' winter range outside the U.S. (Bibles et al. 2002), and no studies have attempted to determine if breeding pairs maintain pair bonds and territories year-round in the LRGV. The LRGV occurs in the subtropical biome, with less seasonality in resources which may favor flexible migratory and dispersal strategies.

Gray Hawks are thought to rely on riparian habitat with tall trees for nesting (Newton 1979, Kaufman 1996, Bibles et al. 2002). Stensrude (1965) found a pair nesting 21.3 m up in a 24.4 m live cottonwood (*Populus* sp.) tree in Arizona, and the following year the pair was found with a new nest approximately 180 m from the location of the previous year. In the LRGV Gray Hawks have been observed nesting in cedar elm (*Ulmus crassifolia*), Mexican ash (*Fraxinus berlandieriana*), and black willow (*Salix nigra*), with an apparent need for tall trees being a possible factor limiting their expansion (Brush 2005).

Knowledge of the breeding biology of Gray Hawks has been slow to accumulate. In 1953 their incubation and fledging periods were still unknown (Sutton 1953). Gray Hawks in Arizona normally lay eggs in first half of May, with young occupying nests from the first week in June through the end of July, and most young fledging by the middle to end of July (Glinski 1998, Corman 2005). While their typical clutch size is 2-3 eggs (Newton 1979), Galindo et al. (2016) discovered a nest in Bentsen-RGV State Park with 5 nestlings that all successfully fledged. The primary prey delivered to the nestlings were hispid cotton rats (*Sigmodon hispidus*) and other rodents.

Knowledge of Gray Hawk habitat use remains anecdotal. Typically thought of as occurring in natural habitat, some recent papers have mentioned use of human-influenced habitats (Bibles et al. 2002). The Gray Hawk has been described as a species that may possibly nest near houses (Bibles et al. 2002, Dunne 2006). In the LRGV, a pair of Gray Hawks nested in a park in southern Hidalgo County heavily used by people on weekends, but this was adjacent to large tracts of natural habitat (T. Brush, personal communication). 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, Gray Hawks had been observed nesting in residential yards (T. Brush and W.S. Clark, personal communications). This suggested that the status of Gray Hawks in urban areas needed further study, especially given the growth of urban areas and limited amount of suitable natural habitat.

The total U.S. population of Gray Hawks is likely small. Kaufman (1996) estimated there were not more than 50 pairs of Gray Hawks in the U.S., Bibles et al. (2002) estimated fewer than 100 nesting pairs, and Alderfer (2014) considered the species stable or possibly expanding, with an estimated 80 breeding pairs. Williams and Krueper (2008) found Gray Hawk numbers to be increasing in Arizona, New Mexico, and Texas, with the increase in numbers along with a northward expansion being possibly linked to rising global and regional annual temperatures increasing favorable habitat and increased abundance of prey.

In general, raptors are particularly sensitive to habitat loss and fragmentation (Glinski 1986, Whaley 1986, Cruz et al. 2021); thus, we must fully understand the Gray Hawks' breeding and non-breeding habitats in south Texas to effectively protect their populations (Carrete et al. 2009, Brown et al. 2014). This study focused on two aspects of their biology: juvenile dispersal as well as home range dynamics of adults in the study area of Hidalgo and Cameron Counties in the LRGV, a subtropical biome with less extreme variation in year-round resources than in other portions of their U.S. range (Figure 1). Using direct observation of color-banded individuals, GPS-GSM transmitters, and VHF transmitters I determined how long fledglings remained near their nest, and how far they travelled after dispersing. In addition, the GPS-GSM transmitters allowed me to determine home range sizes of adult Gray Hawks in the LRGV.

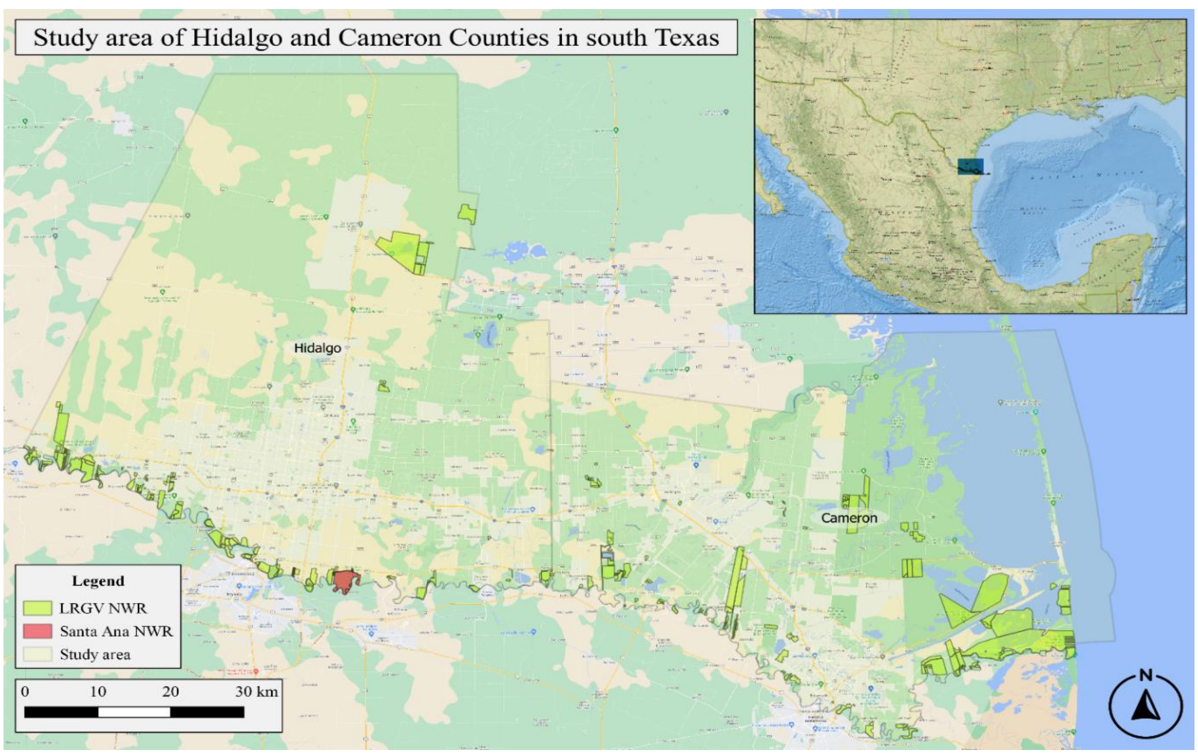


Figure 1. Map of the Study Area in South Texas.

CHAPTER II

METHODS

Study Area

This study was conducted from December 2019 to August 2021. I was initially shown the locations of 11 Gray Hawk nesting areas, with six surrounded by natural areas and five in urban areas. I searched for additional nest sites of Gray Hawks within the study area early in the breeding season and considered sites occupied if a pair was located and displayed behavior such as territorial vocalizations or courtship display flights associated with nesting activities (Bibles and Mannan 2004). Stensrude (1965) observed a pair of Gray Hawks in Arizona over a three-month period from late February to late May and found the birds were most active around 8 or 9 a.m., which is when I focused attempts on locating nests. I also searched at other times of day, since Gray Hawks may vocalize regularly during the breeding season.

Data Collection

I considered a nest site occupied if it contained a nest and attending pair, if there were one or more hawks defending a new or refurbished nest, or if I observed a food delivery to the nest site (Stout et al. 2007). I considered the nest site to be the area immediately surrounding the nest (Tapia et al. 2007). Once a nest tree was located, I recorded the diameter at breast height (DBH) using a fabric diameter tape, the height of each nest tree and the nest using a Nikon Forestry Pro II Laser Rangefinder/Hypsometer, and identified the tree species (Tapia et al. 2007). Nest checks were not performed while the nest contained eggs or nestlings under two weeks old to reduce the risk of nest desertion (Bloom 1974). If nest height allowed, I performed checks using a wireless cavity inspection camera (www.ibwo.org) and a 15 m Crain CMR Series fiberglass measuring rod. Before inspecting or climbing to a nest I ensured my presence was known to reduce the risk of a startled parent trampling eggs or young (Fyfe and Olendorff 1976).

When possible, I climbed nest trees to band nestlings ≤2 weeks prior to the normal fledging age of 42 days (Bibles and Mannan 2004), ideally around 21 days when they were half of adult body mass (Hull and Bloom 2001). Banding at nests occurred prior to noon to ensure birds were not exposed to excessive heat (Fyfe and Olendorff 1976). All birds were fitted with a USGS aluminum band, and a color band (Acraft Sign & Nameplate Co. Ltd., Edmonton, Alberta, Canada). Nestlings were lowered to the ground for increased safety while attaching bands (Hull and Bloom 2001).

Select Gray Hawks were fitted with a 10g OrniTrack-10 or 12g OrniTrack-E10 solar powered GPS-GSM/GPRS/3G tracker (Ornitela, UAB, Vilnius, Lithuania; www.ornitela.com), or a 13g Raptor AWE-R-13 149-152 MHz VHF transmitter (American Wildlife Enterprises, Monticello, Florida, USA). I began the study with 14 OrniTrack-10, 15 OrniTrack-E10, and 15 Raptor AWE-R-13 transmitters. I allotted 15 of the GPS-GSM transmitters for adults and 14 for juveniles to obtain nearly equal representation of life history stages in my sample. No preference was given to sex of either adults or juveniles and, when selecting fledged juveniles, preference was given to birds that had been banded as nestlings. The 15 VHF transmitters were reserved for adults, again with no preference given to sex; I did not want to deploy them on juveniles due to the limited battery life of approximately two years.

I fit backpack-type harnesses to adults and fledglings because they can be used to track birds over multiple years (Walls and Kenward 2007). I 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 in press). To avoid desertion of nests, no hawks were trapped and tagged while they were incubating.

To capture free-flying Gray Hawks, I used several standard trap types, mainly the bal-chatri, but also a phai, bow net, and a mist net with a mounted Great Horned Owl (*Bubo virginianus*) lure near the nest sites (Bloom et al. 2007). Audio playback was authorized on all banding permits and used sparingly when surveying for Gray Hawks and when trapping. While trapping Gray Hawks with a bal-chatri, I used 8-10 cm nooses made from 30 lb monofilament fishing line (Bub 1991). Birds received one band on each leg, a numbered USGS aluminum band and a color band. 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). I chose black and orange for the color bands to ensure the colors would be easy to distinguish from each other (Howitz 1981, Varland et al. 2007). The color banding aspect of this project was publicized at least once every three months at local parks and through other means to ensure a similar resighting probability throughout the duration of the study (Varland et al. 2007).

To ensure birds were not negatively impacted by additional weight, I adhered to the general rule of tags weighing less than 3% of the bird's body mass (Kenward 2001). I used a combination of size and measurements to determine the sex of Gray Hawks, recording the mass, wing chord, tail length, hallux claw length, and culmen from cere length of birds out of the nest; mass was the only measurement recorded for nestlings (Hull and Bloom 2001, Pyle 2008). Females are approximately 10 percent larger than males with no overlap in mass of adult birds (Bibles et al. 2002). This size difference was used to determine 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).

I included every nest that I found within Cameron and Hidalgo Counties in the sample and attempted to trap every Gray Hawk located. Breeding attempts were considered successful if one or more young were raised to an advanced nestling stage (Stout et al. 2007). Nests were considered successful if fledglings were observed within 2 weeks of leaving the nest (Bibles and Mannan 2004). The area fledglings used while still dependent on adults for food was defined as the post-fledging area (Harrower et al. 2010). Habitat was classified as either natural or urban. I classified a territory as urban if the 95% BB home range contained homes, commercial structures, or a mixture of the two, and more than 50% of a bird's GPS fixes were near these structures.

For hawks mounted with VHF transmitters, I recorded whether present or absent during the winter in each applicable territory using a folding 3-element Yagi antenna and R-1000 telemetry receiver (Communications Specialists, Inc., California, USA). Locations were obtained at least twice per month from November through January, and at different times of day (Walls and Kenward 2007).

Analyses

Home range size was calculated by determining 20%, 50%, and 95% utilization distributions to determine where the birds spend 20% of their time, a 50% core area, and the outer 95% extent of their home ranges respectively (Moss et al. 2014). I used the OrniTrack-10 and OrniTrack-E10 GPS locations obtained through the OrniTrack Control Panel (https://www.glosendas.net/cpanel/) and analyzed using R 4.0.3 to calculate and compare home range sizes for birds in our study area. Home range and winter territory sizes were calculated using the minimum convex polygon estimator (MCP) (Mohr 1947), the estimation of kernel home-range (KDE) (Worton 1995), and the estimation of kernel Brownian bridge home-range (BB) (Horne et al. 2007) methods within the CRAN package *adehabitatHR* 0.4.19. Because small sample sizes precluded the assumption of normally distributed data and visual inspection showed the data were right-skewed, I compared the home ranges using the Wilcoxon rank sum exact test with an alpha level of 0.05. I used QGIS 3.14.15-Pi for spatial analysis and mapping. The *kernelUD* function would not converge when the smoothing parameter was set to the least-square cross validation method, instead I used h = 70 as the smoothing factor of with a grid value of 500 for all adult home range and juvenile winter territory KDE analyses.

I defined dispersal as the date a juvenile moved > 1 km from its natal area without returning for the next five days. Straight-line distance dispersed was the distance from the nest coordinates to the center of the 50% MCP winter territory. Beginning of spring movements was defined as the date juveniles began to venture > 5 km from the boundary of their winter territory. Finally, I ran Pearson's product-moment correlation test to determine if there was a correlation between the number of GPS fixes and the sizes of adult home ranges and juvenile winter territories as a check to determine if home range sizes increased as the number of GPS fixes increased.

CHAPTER III

RESULTS

During this study 112 Gray Hawks were color banded: 62 males and 50 females. Fifteen VHF transmitters were deployed on adults, four on males and 11 on females. All 29 GPS-GSM transmitters were deployed, seven were recovered and subsequently redeployed on other Gray Hawks, and five were lost. Throughout the study eight juvenile males, 16 adult males, six juvenile females, and six adult females were tracked via GPS-GSM transmitters. Fifty-four Gray Hawk territories were located, 50 of which were occupied by a pair of Gray Hawks, and 24 of these were in urban areas.

I located a total of 25 nests during this study. Twenty nests produced young, two failed, and three I was unable to monitor because I could not obtain access to the sites. I found the nests of seven Gray Hawk pairs in both 2020 and 2021. These pairs all used the same species of tree for nesting both years. However, all seven used a unique set of tree species, and only one pair reused their nest from the previous year. The pair that reused their nest from 2020 used a Rio Grande ash in the front yard of a home in Harlingen, TX.

Gray Hawks nested in a variety of tree species to include Washingtonia fan palm (*Washingtonia robusta*), pecan (*Carya illinoinensis*), eastern cottonwood (*Populus deltoides*), tepeguaje (*Leucaena pulverulenta*), southern live oak (*Quercus virginiana*), sugar hackberry (*Celtis laevigata*), cedar elm (*Ulmus crassifolia*), Rio Grande ash (*Fraxinus berlandieriana*), and Australian pine (*Casuarina equisetifolia*). The average diameter at breast height was 61.0 cm (range: 20.0-137.8 cm, *n* = 13), the average nest height was 12.0 m (range: 7.8-18.6, *n* = 14), and the average nest tree height was 15.1 m (range: 10.9-22.7, *n* = 14).

Adult Home Ranges

The 95% BB annual home range sizes for adult Gray Hawks (median = 452 ha, mean = 782 ha, SE = 217 ha, *n* = 22) differed by sex and by habitat. The median home range for males was 580 ha (*n* = 16) while for females it was 123 ha (*n* = 6), more than four times smaller than for males. Gray Hawks in natural areas (median = 600 ha, *n* = 14) had home ranges that were more than four times larger than in urban areas (median = 142 ha, *n* = 8). Results of MCP, KDE, and BB home range analyses are presented in Table 1. The Pearson's product-moment test for correlation between the number of GPS fixes and the 95% BB home range sizes was positive and statistically not significant (r = 0.28, p = 0.20).

Gray Hawk territories were occupied and vigorously defended year-round by the pair present in their territory throughout the year, and with some pairs observed sitting within 1 m of each other during the winter months. Gray Hawks would respond aggressively to playback every month of the year. In most cases, five minutes (often less) of Gray Hawk alarm or territorial calls would result in both adults flying in and giving their alarm calls, territorial calls, or both. Adults I believed to be unmated males would respond just as aggressively to defend their territories, also regardless of time of year.

Table 1. Home Range Sizes of 22 Adult Gray Hawks.

20%, 50%, and 95% utilization distributions for adult Gray Hawks using three different methods of calculation. Males are identified by a black color band and two-digit code and females by an orange color band with a two-digit alphanumeric code. Also listed are the total number of days the bird was tracked plus the total fixes obtained, and a classification of whether the home range was in a natural or urban area.

Bird ID	Urban v. Natural	Number of GPS fixes	Number of days tracked	Minimum Convex Polygon			Kernel Density Estimate			Brownian Bridge Movement Method		
				20% UD (ha)	50% UD (ha)	95% UD (ha)	20% UD (ha)	50% UD (ha)	95% UD (ha)	20% UD (ha)	50% UD (ha)	95% UD (ha)
Black 0/3	Urban	500	14	0.5	2.7	22	1.6	5.4	38	2.8	15	117
Black 0/4	Urban	1143	65	3.9	11	73	3.6	12	79	5.4	23	167
Black 0/6	Natural	6225	350	1.8	8.0	105	2.7	9.8	99	5.3	24	238
Black 0/7	Natural	16443	524	6.4	18	121	3.9	16	123	9.4	46	574
Black 0/8	Natural	2739	97	3.9	16	60	3.8	14	66	21	93	1941
Black 0/9	Natural	10095	330	2.1	9.2	54	3.3	11	51	3.8	14	93
Black 1/1	Natural	3618	101	5.1	16	79	3.7	16	80	6.6	30	281
Black 1/2	Natural	2196	107	8.8	18	69	5.7	18	79	10	35	326
Black 1/3	Natural	12539	488	5.4	15	307	4.3	17	186	9.0	54	587
Black 1/4	Urban	12368	451	3.0	6.5	56	1.7	6.6	41	3.8	19	330
Black 2/9	Natural	11133	404	3.7	17	144	4.2	16	99	12	49	613
Black 3/1	Natural	4821	368	1.8	12	92	2.3	11	91	13	70	706
Black 3/2	Natural	8867	360	2.5	7.4	40	2.8	9.7	47	9.1	51	760
Black 3/3	Natural	11532	269	29	50	7163	4.8	27	686	31	250	4515
Black 3/5	Natural	4041	155	17	53	802	5.7	19	205	23	140	2091
Black 3/6	Natural	6355	331	18	34	466	2.8	13	192	17	114	1083
Orange 0/D	Natural	287	32	1.4	6.8	30	3.0	11	54	7.5	28	166
Orange 0/H	Urban	2678	401	6.1	13	133	3.9	13	88	12	54	1265
Orange 0/K	Urban	229	18	0.7	1.9	14	1.6	5.9	37	2.0	8.8	69
Orange 0/P	Urban	5094	526	0.2	0.5	47	1.1	3.9	53	6.7	50	1143
Orange 0/S	Urban	444	25	0.4	1.0	3.7	1.2	3.6	16	1.3	5.0	66
Orange 1/W	Urban	4318	287	0.7	1.7	43	1.3	4.8	45	1.8	9.1	80
Mean		**5803**	**260**	**5.6**	**14**	**451**	**3.1**	**12**	**112**	**9.7**	**54**	**782**
SE		**1014**	**38**	**1.5**	**3.0**	**322**	**0.3**	**1.2**	**29**	**1.6**	**12**	**217**

Home range sizes were, on average, larger when calculated with the minimum convex polygon estimator compared to the kernel home-range estimator, and the kernel Brownian bridge home-range estimator produced the largest areas out of the three methods. The difference in mean home range size (50% and 95% utilization distributions for each of the three methods) was statistically significant for males (n = 16) vs. females (n = 6) and for urban (n = 8) vs. natural (n = 14) habitats for all home range sizes and methods except two: the difference in means between males and females for the 95% KDE (W = 73, P = 0.07) and between males and females for the 95% BB (W = 71, P = 0.10). Wilcoxon rank sum exact test results are presented in Table 2.

Table 2. Wilcoxon Test Results Comparing Adult Home Ranges.
Wilcoxon rank sum exact test results comparing home range sizes of adult male Gray Hawks versus adult females, and adult Gray Hawks in urban versus natural areas.

Groups tested	**50% MCP**	**95% MCP**	**50% KDE**	**95% KDE**	**50% BB**	**95% BB**
Male v. Female	W = 87, P = 0.002	W = 80, P = 0.02	W = 83, P = 0.008	W = 73, P = 0.07	W = 78, P = 0.03	W = 71, P = 0.10
Urban v. Natural	W = 9, P < 0.001	W = 21, P = 0.02	W = 11, P = 0.001	W = 21, P = 0.02	W = 13, P = 0.002	W = 19, P = 0.01

Adult Gray Hawks in the study area did not migrate. All adults tracked via GPS-GSM or VHF remained in their territories year-round with the pairs remaining together. Very little overlap occurred between neighboring birds with GPS-GSM trackers. Two males, Black 3/3 and Black 3/5, 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; an example of the forays made by Black 33 is shown in Figure 2. Without these two individuals, the 95% BB median home range size for males changes from 580 ha (n = 16) to 452 ha (n = 14), still more than three times larger than median home range size for females. Home ranges within the study area are shown in Figure 3.

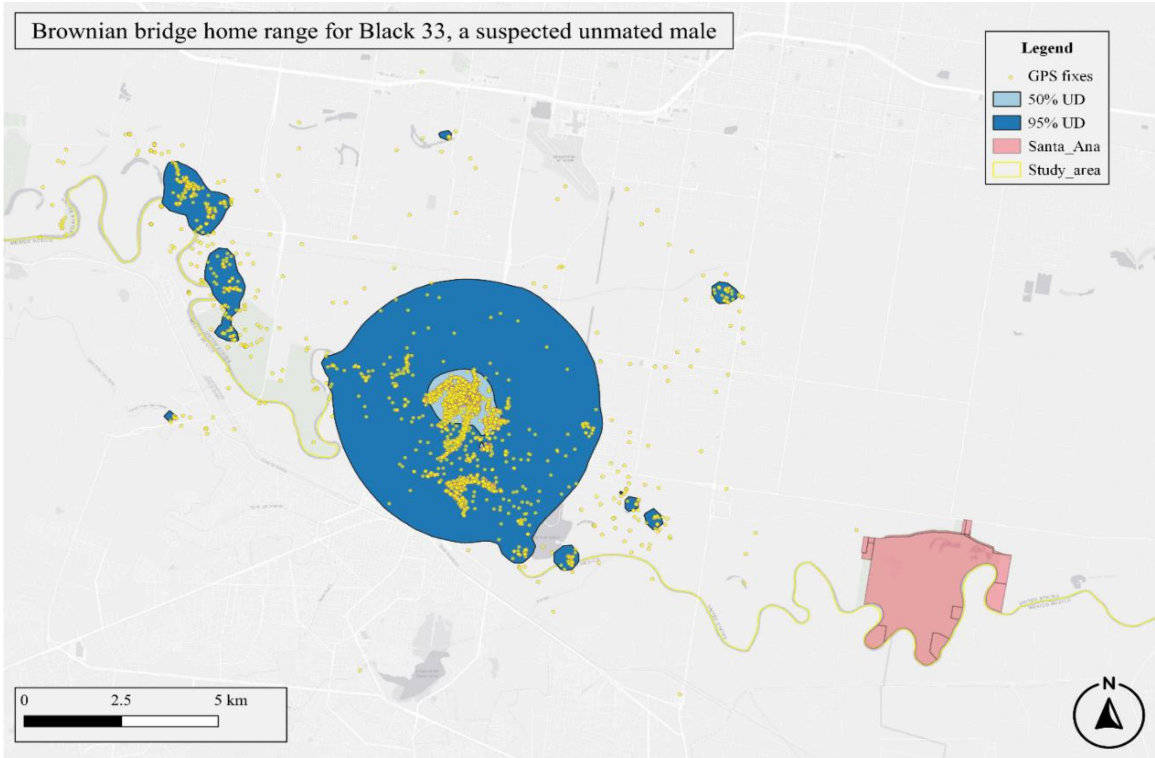


Figure 2. Map Showing the Home Range of a Presumably Unmated Adult Male.

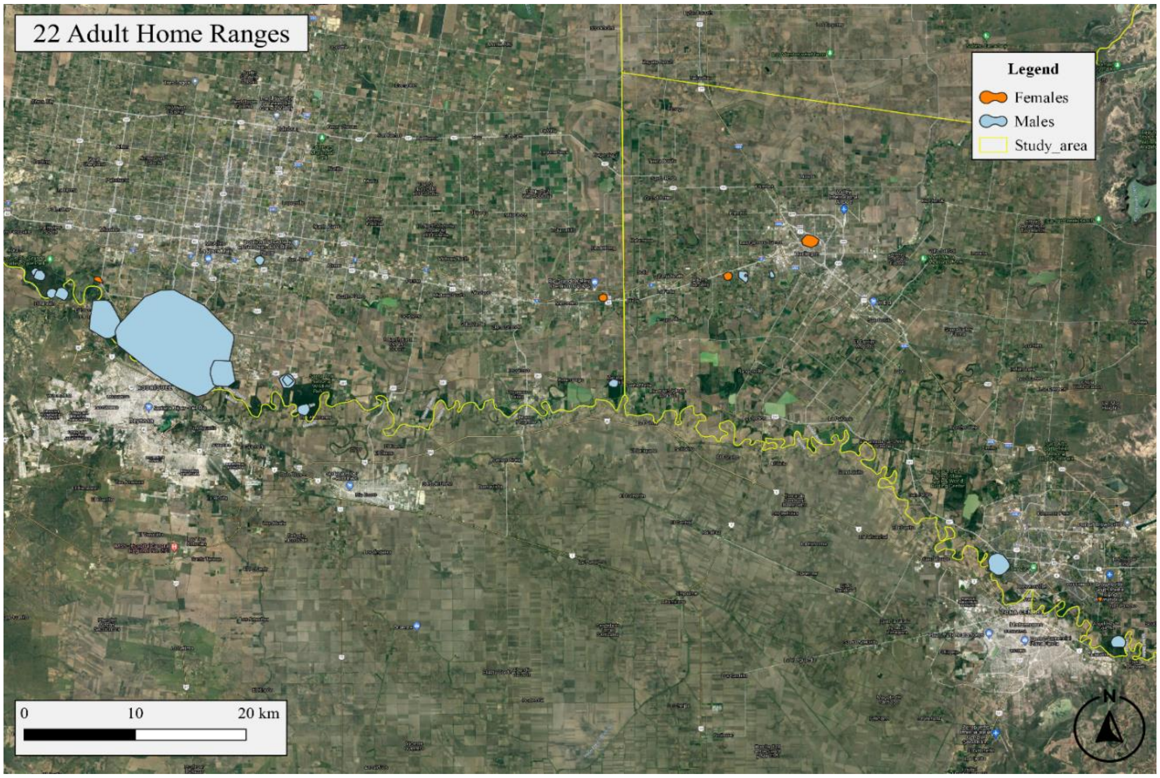


Figure 3. Map Showing the Home Ranges of 22 Adults.

Juvenile Dispersal

The mean dispersal date for the 14 juveniles tracked was August 13, 2020 (median = August 11, range: August 1 to September 9). Locations of winter territories varied widely with most juveniles wintering in the LRGV, but three travelled to Central America, two males and one female. Accordingly, the mean straight-line distance dispersed for males (*n* = 8) of 530 km was greater than the mean distance of 362 km for females (*n* = 6). However, the median for females was 39 km versus 7 km for males. The difference in straight-line distance (W = 17, *P* = 0.63) was statistically not significant for males vs. females. Juvenile movement dates and straight-line distances are listed in Table 3, total dispersal movements are shown in the appendix.

Table 3. Juvenile 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 territory in the winter of 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 territory (50% MCP). Three juvenile males, Black 1/7, Black 1/9, and Black 2/1, stopped transmitting prior to establishing winter territories.

Bird ID	Dispersed (2020)	Stopped for the winter (2020)	Straight-line distance (km)	Started moving in spring (2021)
Black 1/7	Aug 19	NA	NA	NA
Black 1/9	Aug 12	NA	1,906	NA
Black 2/0	Aug 1	Nov 18	0.6	Mar 18
Black 2/1	Aug 2	NA	1,773	NA
Black 2/2	Aug 11	Nov 21	3.3	Apr 20
Black 2/3	Aug 9	Nov 30	5.2	Apr 11
Black 3/0	Aug 10	Nov 13	7.0	Mar 24
Black 3/4	Sep 9	Dec 24	15	Mar 20
Orange 0/Z	Aug 3	Nov 1	12	Mar 20
Orange 1/A	Aug 5	Nov 7	1.1	Mar 3
Orange 1/E	Aug 26	Dec 22	34	Mar 15
Orange 1/H	Aug 23	Nov 11	45	Feb 23
Orange 1/K	Aug 17	Nov 19	1,644	Mar 27
Orange 1/N	Aug 6	Dec 16	437	Apr 5

Of the 14 juveniles with GPS-GSM transmitters, there were eight males and six females, including three sets of siblings. Dispersal of both females from a nest in Harlingen (Orange 1H and Orange 1K) are shown in Figure 4; dispersal maps for all 14 juveniles are included in the appendix. Black 22 and 23 dispersed within two days of each other and travelled mainly within the study area, both wintering relatively close to their natal areas. The three from the nest in

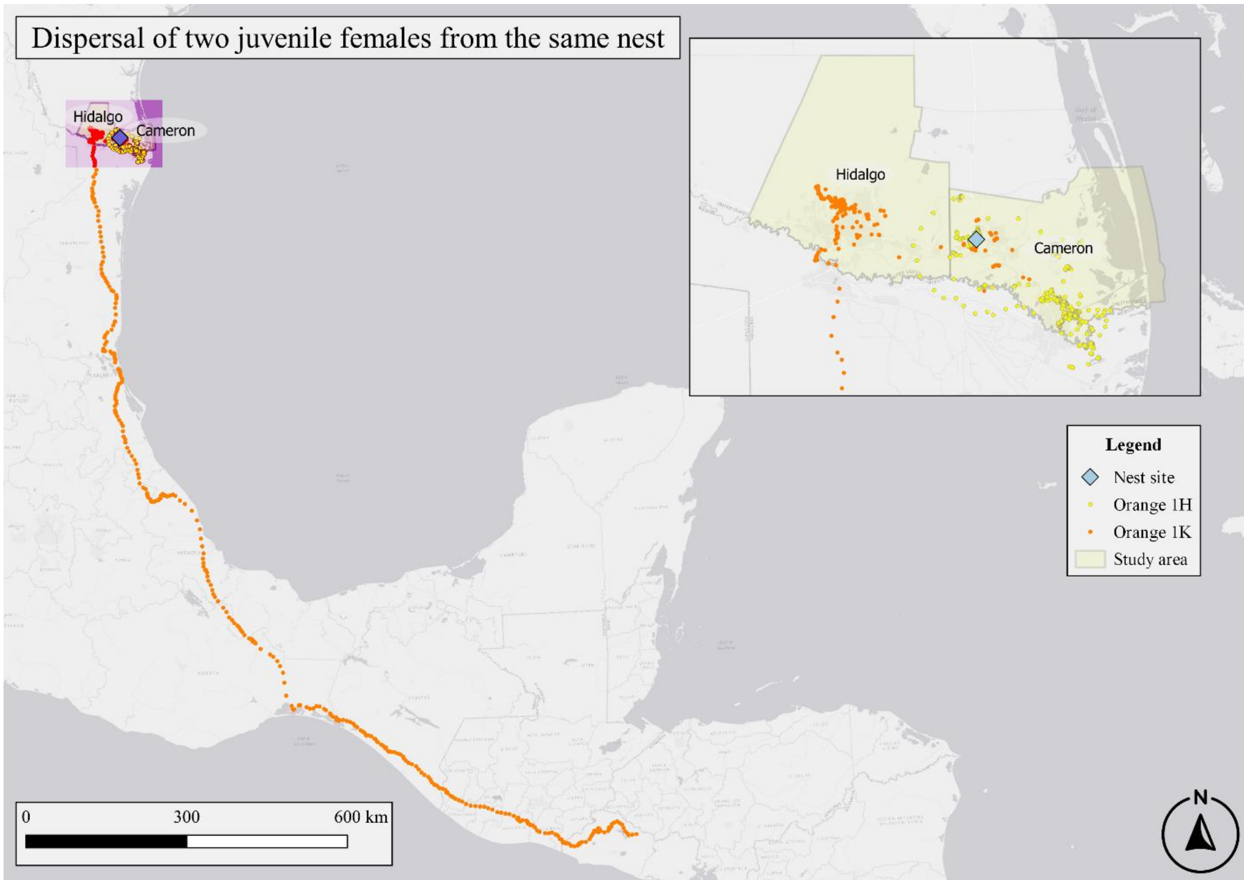


Figure 4. Dispersal Patterns of Two Juvenile Females from the Same Nest.

Mercedes 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 juvenile males, Black 19 and Black 21, travelled to Central America where they stopped transmitting. Black 19 reached Nicaragua and Black 21 reached Honduras where I presume both died, though it is possible they travelled to areas with no cellular coverage.

Another male, Black 17, stopped transmitting and was presumed dead around October 2, 2020, in Cameron County, Texas. These three did not settle on winter territories, but Black 19 and Black 21 were included in the analysis of dispersal distance. Straight-line distance dispersed for Black 19 and Black 21 was calculated as the distance from the nest coordinates to the last GPS fix obtained.

The average date juveniles settled on a winter territory was November 25, 2020 (median = November 19, range: November 1 to December 24). Nine of the 11 juveniles settled for the winter in urban areas, the other two were in natural areas in Mexico just south of Santa Ana NWR that were relatively close to the international border. Four juveniles completely left the U.S. for the winter, including the two males that stopped transmitting after reaching Central

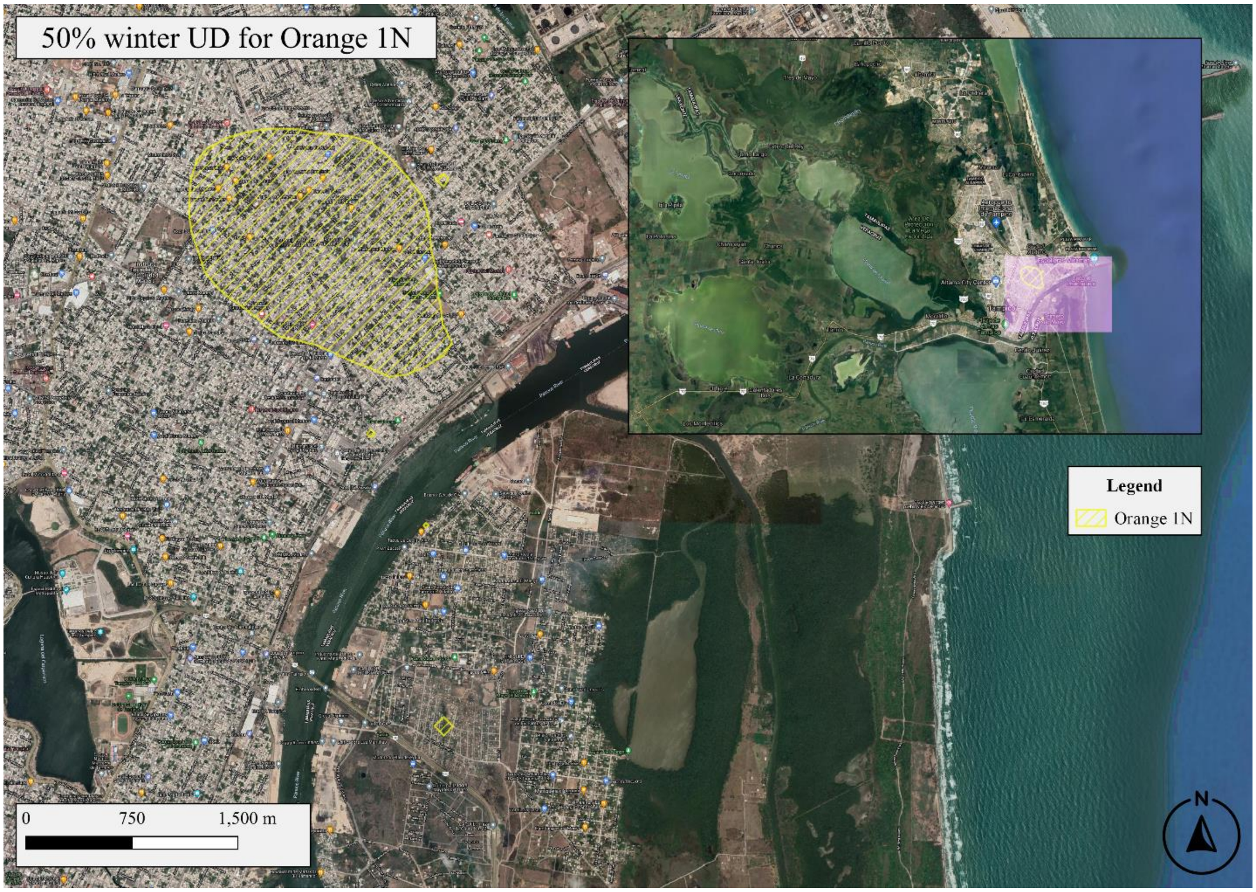


Figure 5. Map Showing a Juvenile Female's Winter Territory in Tampico, Mexico.

America. One female spent the winter in the city of Tampico in Tamaulipas, MX (Figure 5), the other female wintered in El Salvador. Orange 1K departed the U.S. on October 21, Black 19 departed October 27, Black 21 departed October 28, and Orange 1N waited until December 3 to depart the U.S. and head to Tampico.

The three Gray Hawks that travelled to Central America followed very similar routes (Figure 6). The female that wintered in Mexico returned April 6, 2021, and the female from El Salvador returned April 14. Of these four hawks, three were from nests in urban areas, two females from Harlingen, TX, and one male from McAllen, TX. The fourth bird, Black 21, was a male from a nest in a natural area near Santa Ana NWR.

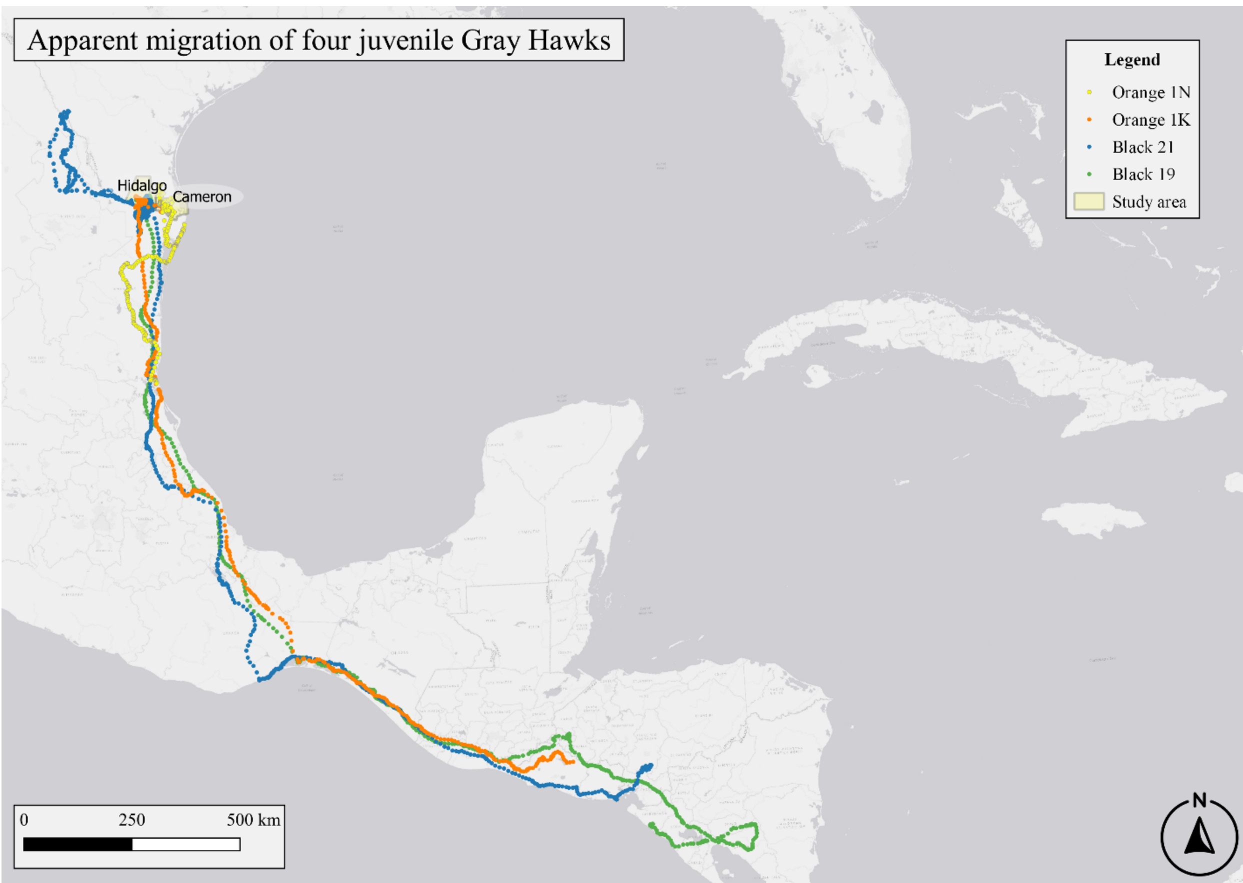


Figure 6. Map Showing Apparent Migration of Four Juveniles.

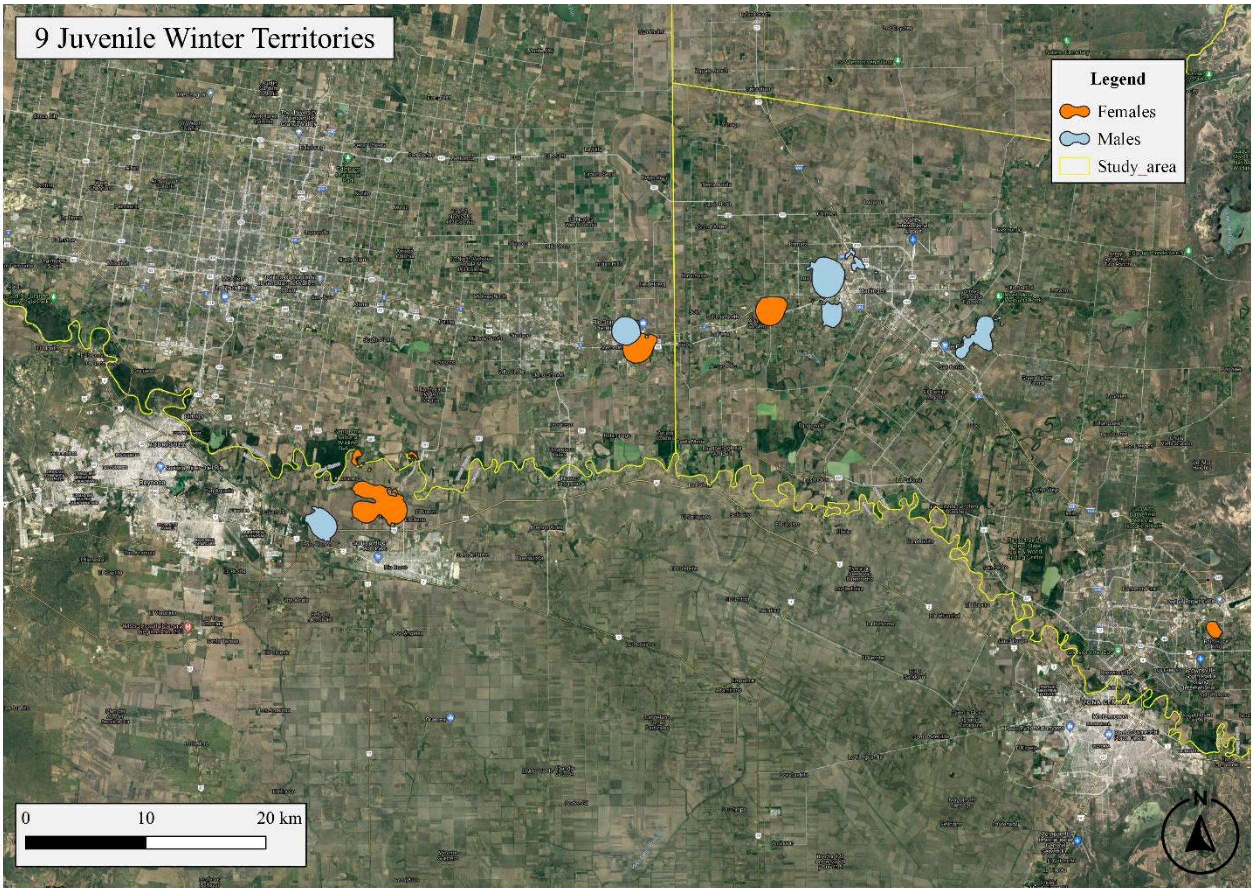


Figure 7. Map Showing Winter Territories of Nine Juveniles.

The 95% BB winter territory sizes for juvenile Gray Hawks (median = 507 ha, mean = 707 ha, SE = 203 ha, *n* = 11) did not differ by sex or by habitat (Figure 7). The median winter territory size for males was 503 ha (*n* = 5) and 526 ha (*n* = 6) for females. Gray Hawks in natural areas (median = 872 ha, *n* = 2) had winter territories that were larger than hawks in urban areas (median = 507 ha, *n* = 9), but the differences were statistically not significant (W = 6, *P* = 0.58); Wilcoxon rank sum exact test results are presented in Table 4. The estimation of kernel Brownian bridge home-range again produced the largest areas out of the three methods. Winter territory sizes are presented in Table 5. The Pearson's product-moment test for correlation between the number of GPS fixes and the 95% BB winter territory sizes was positive and statistically not significant (r = 0.18, p = 0.60).

Table 4. Wilcoxon Test Results Comparing Juvenile Winter Territories.
Wilcoxon rank sum exact test results comparing winter territory sizes of juvenile male Gray Hawks versus juvenile females, and juvenile Gray Hawks wintering in urban versus natural areas.

Groups tested	**50% MCP**	**95% MCP**	**50% KDE**	**95% KDE**	**50% BB**	**95% BB**
Male v. Female	W = 16, *P* = 0.93	W = 14, *P* = 0.93	W = 16, *P* = 0.93	W = 16, *P* = 0.93	W = 16, *P* = 0.93	W = 14, *P* = 0.93
Urban v. Natural	W = 2, *P* = 0.15	W = 5, *P* = 0.44	W = 6, *P* = 0.58	W = 4, *P* = 0.33	W = 3, *P* = 0.22	W = 6, *P* = 0.58

The average date juveniles departed their winter territories in the spring of 2021 was March 23 (median = March 20, range: February 23 to April 20). Of the 11 juveniles, none settled in a 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 would return to spend time in their winter territory before continuing to roam the LRGV. Three Gray Hawk territories within the study area contained adult males paired with juvenile females; these made no breeding attempts in the spring of 2021.

Table 5. Winter Territory Sizes of 11 Juvenile Gray Hawks.
20%, 50%, and 95% utilization distributions for juvenile Gray Hawks on their winter territory using three different methods of calculation. Males are identified by a black color band and two-digit code and females by an orange color band with a two-digit alphanumeric code. Also listed are the total number of days the bird was tracked plus the total fixes obtained, and a classification of whether the home range was in a natural or urban area.

Bird ID	**Urban v. Natural**	**Number of GPS fixes**	**Number of days tracked**	**Minimum Convex Polygon**			**Kernel Density Estimate**			**Brownian Bridge Movement Method**		
				20% UD (ha)	50% UD (ha)	95% UD (ha)	20% UD (ha)	50% UD (ha)	95% UD (ha)	20% UD (ha)	50% UD (ha)	95% UD (ha)
Black 2/0	Urban	1399	119	2.0	3.0	105	1.3	7.2	86	8.8	44	447
Black 2/2	Urban	6170	149	13	36	991	4.8	24	238	12	67	879
Black 2/3	Urban	5457	132	5.0	20	242	5.0	18	160	6.9	32	310
Black 3/0	Natural	4915	130	3.1	81	273	5.1	22	180	12	68	503
Black 3/4	Urban	3928	85	70	149	624	10	46	318	13	70	553
Orange 0/Z	Urban	2818	139	15	33	278	6.0	24	180	14	58	507
Orange 1/A	Urban	1187	115	2.1	12	307	3.4	14	132	12	57	546
Orange 1/E	Natural	2613	83	159	200	1248	3.6	33	462	12	100	1241
Orange 1/H	Urban	1062	104	1.8	2.7	43	1.5	5.8	47	4.0	19	132
Orange 1/K	Urban	1960	127	3.6	11	61	3.6	11	66	5.5	19	155
Orange 1/N	Urban	705	109	40	150	1025	13	58	454	48	240	2509
Mean		**2929**	**118**	**29**	**63**	**472**	**5.2**	**24**	**211**	**13**	**70**	**707**
SE		**578**	**6.4**	**15**	**21**	**130**	**1.0**	**4.9**	**44**	**3.6**	**18**	**203**

CHAPTER IV

DISCUSSION

My objectives for this study were to determine how long fledglings remained in their natal area, how far they dispersed, and to determine home range sizes of adult Gray Hawks in the study area. By determining juveniles' dispersal dates and distances I have filled a knowledge gap in the life history of Gray Hawks. To the best of my knowledge home range sizes have only been documented in one study, and this was for birds in Arizona (Bibles 1999). By meeting my objective to determine home range size for adults I have documented new information about the Gray Hawk population in Texas, which is state listed as threatened (Texas Parks and Wildlife Department n.d.).

The two adult males I 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, or possibly a better territory. However, given how difficult it can be to locate Gray Hawks, I cannot say with any certainty that they did not have a mate. Mated males also made occasional forays well outside of their core area, but the two suspected unmated males made forays more frequently than other males.

Of the 15 adult Gray Hawks with VHF transmitters, most were always able to be detected from the exact location where they were captured. Only one hawk, an adult female, was difficult to locate during the winter since she could not always be detected from where she was captured. This female spent some time during the winter across the Rio Grande River 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 GPS-GSM transmitter. Taken together, these results provide strong evidence that pairs maintained their pair bond in the same territory year-round.

Adult home range sizes for males were significantly larger than for females, though my sample of females with GPS-GSM transmitters was small (n = 6). This was in part due to the decision not to target adults based on sex and exacerbated by some hawks removing their Teflon harness or covering their OrniTrack-10 transmitter with nape feathers (Stewart and Millsap in press). The large number of fixes from females at the nest while incubating could possibly account for some of the difference in home range size between males and females. Alternatively, breeding females may remain close to the nest post-incubation to facilitate brooding and protecting nestlings. However, three of the six female home ranges calculated were very short time spans prior to the breeding season and did not include incubation.

Of the three methods used to calculate adult home ranges and juvenile winter territories the estimation of kernel Brownian bridge home-range is the most appropriate method for this dataset. This is due to the very large number of GPS fixes obtained, and the relatively short time span between fixes. Most of the fixes were obtained 30 min apart, with some as frequent as 15 min and some 8 hrs apart. Fixes obtained so close to each other will be autocorrelated and cannot be considered independent from one another, the BB method does not rely on the assumption of uncorrelated locations when calculating home range size.

This study supports previous studies suggesting Gray Hawks are more of a generalist, being able to use what best suits their needs, both with prey availability in the home range, as well as tree species that allow for sufficient nest height (Bibles 1999, La Porte et al. 2020). I found Gray Hawks nesting in nine different species of tree in both natural and urban habitats. An example of their adaptability is a pair that nested in two different Washingtonia palm trees that had no green fronds growing out of the top, but enough of the skirt remained to help support the nest. However, the concentration of adult territories located in remnants of natural vegetation, mostly located close to the Rio Grande River, suggests this natural habitat is preferred. More study is needed to identify the importance of specific habitat features.

The difference in dispersal behavior between Orange 1H and Orange 1K, the two females from the same nest in Harlingen, was very surprising. They moved throughout the study area, both with a small number of GPS fixes just across the border in Mexico, until October 21, 2020, when Orange 1K left the U.S., eventually arriving in El Salvador where she spent the winter, while her sibling, Orange 1H, remained within the LRGV for the winter. In birds, female-biased dispersal is common (Dale 2001) and my results suggest that even closely genetically related individuals of Gray Hawks show flexibility in dispersal strategies. Given the migratory nature of temperate populations in the rest of the U.S. population (Bibles et al. 2002) and year-round residency in the LRGV (this study), juvenile dispersal may be evolutionary labile.

Four of the juvenile Gray Hawks wintered well outside of the study area, three of them in Central America. Of the three juveniles that travelled to Central America, their departure coincided with the timing of fall migration for Gray Hawks in Arizona (Corman 2005). However, juvenile dispersal patterns for the species have not previously been studied. The fourth bird, Orange 1N, departed the study area December 3, 2020, and travelled to Tampico, Mexico, where she wintered within the city, returning to the study area on April 6, 2021. This suggests some Gray Hawks within the LRGV may be migratory and deserves further study.

Considering the tremendous amount of habitat loss and fragmentation throughout the LRGV the Gray Hawk population appears to be doing better than expected, potentially due to their flexibility in the use of urban areas (U.S. Fish and Wildlife Service 2013). Of the 50 pairs of Gray Hawks located within the study area, 21 were confirmed breeders in one or both years. This suggests breeders represent roughly half of the population and that the total U.S. population of Gray Hawks is larger than previously estimated (Kaufman 1996, Bibles et al. 2002, Alderfer 2014). The main population in Texas appears to be in Cameron and Hidalgo Counties within the LRGV, due to higher humidity, the presence of taller nest trees, and probably more profitable foraging habitat. 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 (T. Brush, personal communication).

The LRGV is one of the fastest growing regions of the U.S. and urban sprawl can have important implications for species with inflexible foraging strategies and resource differences between their native habitat and urban habitat. Gray Hawks in natural areas had larger home range sizes than those in urban areas, which could be due to less available habitat for them to occupy in these areas or differences in foraging efficiency or prey abundance. Hawks in urban areas may require less space because of more abundant prey around humans or landscapes that are more open making it easier to locate and capture prey. Future research should compare the diets of Gray Hawks 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 research project, will help inform and guide future conservation efforts.

REFERENCES[1]

Alderfer, J. (Editor) (2014). Gray Hawk. In National Geographic Complete Birds of North America. 2nd edition. National Geographic, Washington DC, USA.

Bibles, B. D. (1999). The relationship between productivity and habitat quality in Gray Hawks. PhD Thesis, University of Arizona, Tucson, AZ, USA.

Bibles, B. D., and R. W. Mannan (2004). Productivity and nest-site characteristics of Gray Hawks in southern Arizona. The Journal of Raptor Research 38:238-242.

Bibles, B. D., R. L. Glinski, and R. R. Johnson (2002). Gray Hawk (*Buteo plagiatus*), version 2.0. In The Birds of North America (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bna.652

Bloom, P. (1974). Some Precautions to be Used in Banding Studies of Nestling Raptors. Western Bird Bander 49:4-5.

Bloom, P. H., W. S. Clark, and J. W. Kidd (2007). Capture Techniques. In Raptor Research and Management Techniques (D. M. Bird and K. L. Bildstein, Editors). Hancock House Publishers. Blaine, WA, USA.

Boal, C. W. (2018). Urban Raptor Communities: Why Some Raptors and Not Others Occupy Urban Environments. In Urban Raptors: Ecology and Conservation of Birds of Prey in Cities (C. W. Boal and C. R. Dykstra, Editors). Island Press, Washington DC, USA.

Brown, J. L., M. W. Collopy, and J. A. Smallwood (2014). Habitat fragmentation reduces occupancy of nest boxes by an open-country raptor. Bird Conservation International 24:364-378.

Brush, T. (2005). Nesting Birds of a Tropical Frontier: The Lower Rio Grande Valley of Texas. Texas A&M University Press, College Station, TX, USA.

Bub, H. (1991). Capture with nooses. In Bird Trapping and Bird Banding (F. Hamerstrom and K. Wuertz-Schaefer, Translators). Cornell University Press, Ithaca, NY, USA.

1. Citation format follows the American Ornithological Society’s instructions for authors.

Carrete, M., J. L. Tella, G. Blanco, and M. Bertellotti (2009). Effects of habitat degradation on the abundance, richness and diversity of raptors across Neotropical biomes. Biological Conservation 142:2002-2011.

Clark, W. S., and P. Pyle (2015). Commentary: A Recommendation for Standardized Age-Class Plumage Terminology for Raptors. The Journal of Raptor Research 49:513-517.

Corman, T. E. (2005). In Arizona Breeding Bird Atlas (T. E. Corman and C. Wise-Gervais, Editors). University of New Mexico Press, NM, USA.

Cruz, C., G. Santulli-Sanzo, and G. Ceballos (2021). Global patterns of raptor distribution and protected areas optimal selection to reduce the extinction crises. Proceedings of the National Academy of Sciences, 118:1-8. https://doi.org/10.1073/pnas.2018203118

Dale, S. (2001). Female-biased dispersal, low female recruitment, unpaired males, and the extinction of small and isolated bird populations. Oikos, 92:344–356. https://doi.org/10.1034/j.1600-0706.2001.920217.x

Davis, L. I. (1955). Checklist of bird species of the Rio Grande Delta region of Texas. Texas Ornithological Society Occasional Papers 1.

Davis, L. I. (1966). Birds of the Rio Grande Delta region, an annotated checklist. Published by the author, Austin, TX, USA.

Dunne, P. (2006). Pete Dunne's Essential Field Guide Companion. Houghton Mifflin Company, New York, NY, USA.

Fyfe, R. W., and R. R. Olendorff (1976). Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service Occasional Paper Number 23.

Galindo, R., M. Gustafson, R. Rodriguez, and W. S. Clark (2016). Gray Hawk fledged five juveniles in south Texas. Bulletin of the Texas Ornithological Society 49:86-87.

Gehlbach, F. R. (1987). Natural history sketches, densities, and biomass of breeding birds in evergreen forests of the Rio Grande, Texas, and Rio Corona, Tamaulipas, Mexico. The Texas Journal of Science 39:241-251.

Glinski, R. L. (1998). Gray Hawk. In The Raptors of Arizona. (R. L. Glinski, Editor). The University of Arizona Press, Tucson, AZ, USA.

Glinski, R. L. (1986). Gray Hawk. In Proceedings of the Southwest Raptor Management Symposium and Workshop. (R. L. Glinski, B. G. Pendleton, M. B. Moss, M. N. LeFranc Jr., B. A. Millsap, and S. W. Hoffman, Editors). National Wildlife Federation Scientific and Technical Series No. 11.

Griscom, L., and M. S. Crosby (1925). Birds of the Brownsville region, southern Texas. The Auk 42:432-440.

Harrower, W. L., K. W. Larsen, and K. A. Stuart-Smith (2010). Movements and Resource Selection of Fledgling Goshawks in Montane Forests of Southeastern British Columbia. The Journal of Wildlife Management 74:1768-1775.

Horne, J. S., Garton, E. O., Krone, S. M., and J. S. Lewis (2007). Analyzing Animal Movements Using Brownian Bridge. Ecology 88:2354-2363.

Howitz, J. L. (1981). Determination of Total Color Band Combinations. Journal of Field Ornithology 52:317-324.

Hubbard, J. P. (1974). The Status of the Gray Hawk in New Mexico. The Auk 91:163-166.

Hull, B., and P. Bloom (2001). The North American Banders' Manual for Raptor Banding Techniques. The North American Banding Council, Point Reyes Station, CA, USA.

Kaufman, K. (1996). Gray Hawk. In Lives of North American Birds. Houghton Mifflin Company, New York, NY, USA.

Kenward, R. E. (2001). A Manual for Wildlife Radio Tagging. Academic Press, San Diego, CA, USA.

Krueper, D. J. (2010). Gray Hawk. In Raptors of New Mexico. (J-L. E. Cartron, Editor). University of New Mexico Press, Albuquerque, NM, USA.

La Porte, A. M., R. W. Mannan, and S. Brewer (2020). Riparian Conservation Facilitated Expansion of Gray Hawks. The Journal of Wildlife Management 84:911–920.

Lockwood, M. W., and B. Freeman (2014). The TOS handbook of Texas birds. Texas A&M University Press, College Station, TX, USA.

McKinney, B. (2002). Checklist of Lower Rio Grande Valley birds, 3rd edition. Valley Nature Center, Weslaco, TX.

Millsap, B. A. (1986). Biosystematics of the Gray Hawk, *Buteo nitidus* (Latham). MSc dissertation, George Mason University, Fairfax, VA, USA.

Millsap, B. A., S. H. Seipke, and W. S. Clark (2011). The Gray Hawk (*Buteo Nitidus*) is two species. The Condor 113:326-339.

Mohr, C. O. (1947). Table of Equivalent Populations of North American Small Mammals. The American Midland Naturalist 37:223-249.

Moss, E. H. R., T. Hipkiss, F. Ecke, H. Dettki, P. Sandström, P. H. Bloom, J. W. Kidd, S. E. Thomas, and B. Hörnfeldt (2014). Home-Range Size and Examples of Post-Nesting Movements for Adult Golden Eagles (*Aquila chrysaetos*) in Boreal Sweden. The Journal of Raptor Research 48:93-105.

Newton, I. (1979). Population Ecology of Raptors. Buteo Books, Vermillion, SD, USA.

Oberholser, H. C. (1974). Gray Hawk. In The Bird Life of Texas. (E. B. Kincaid, Jr., Editor). University of Texas Press, Austin, TX, USA.

Olendorff, R. R. (1972). Weighing and Measuring Raptors. Raptor Research 6:53-56.

Phillips, A., J. Marshall, and G. Monson (1964). The birds of Arizona. University of Arizona Press, Austin, TX, USA.

Pyle, P. (2008). Identification Guide to North American Birds, Part II. Slate Creek Press, Point Reyes Station, CA, USA.

Stensrude, C. (1965). Observations on a pair of Gray Hawks in southern Arizona. The Condor 67:319-321.

Stewart, M. T., and B. A. Millsap (In press). Challenges Adapting a Backpack Harness for Use on Gray Hawks (*Buteo Plagiatus*). Journal of Raptor Research.

Stout, W. E., R. N. Rosenfield, W. G. Holton, and J. Bielefeldt (2007). Nesting Biology of Urban Cooper's Hawks in Milwaukee, Wisconsin. The Journal of Wildlife Management 71:366-375.

Sutton, G. M. (1953). Gray Hawk. The Wilson Bulletin 65:5-7.

Tapia, L., P. L. Kennedy, and R. W. Mannan (2007). Habitat Sampling. In Raptor Research and Management Techniques (D. M. Bird and K. L. Bildstein, Editors). Hancock House Publishers, Blaine, WA, USA.

Texas Parks and Wildlife Department. (2020). *Species of Greatest Conservation Need*. Retrieved October 9, 2021, from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml

Tweit, R. C. (2007). Gray Hawk. In The Texas Breeding Bird Atlas. Texas A&M University System, College Station and Corpus Christi, TX, USA. https://txtbba.tamu.edu

U.S. Fish and Wildlife Service. (2013, May 3). *About the Refuge - Lower Rio Grande Valley*. Retrieved August 24, 2021, from https://www.fws.gov/refuge/Lower_Rio_Grande_Valley/about.html

Varland, D. E., J. A. Smallwood, L. S. Young, and M. N. Kochert (2007). Marking Techniques. In Raptor Research and Management Techniques (D. M. Bird and K. L. Bildstein, Editors). Hancock House Publishers, Blaine, WA, USA.

Walls, S. S., and R. E. Kenward (2007). Radio Tracking. In Raptor Research and Management Techniques (D. M. Bird and K. L. Bildstein, Editors). Hancock House Publishers, Blaine, WA, USA.

Whaley, W. H. (1986). Population ecology of the Harris' Hawk in Arizona. Raptor Research 20:1-15.

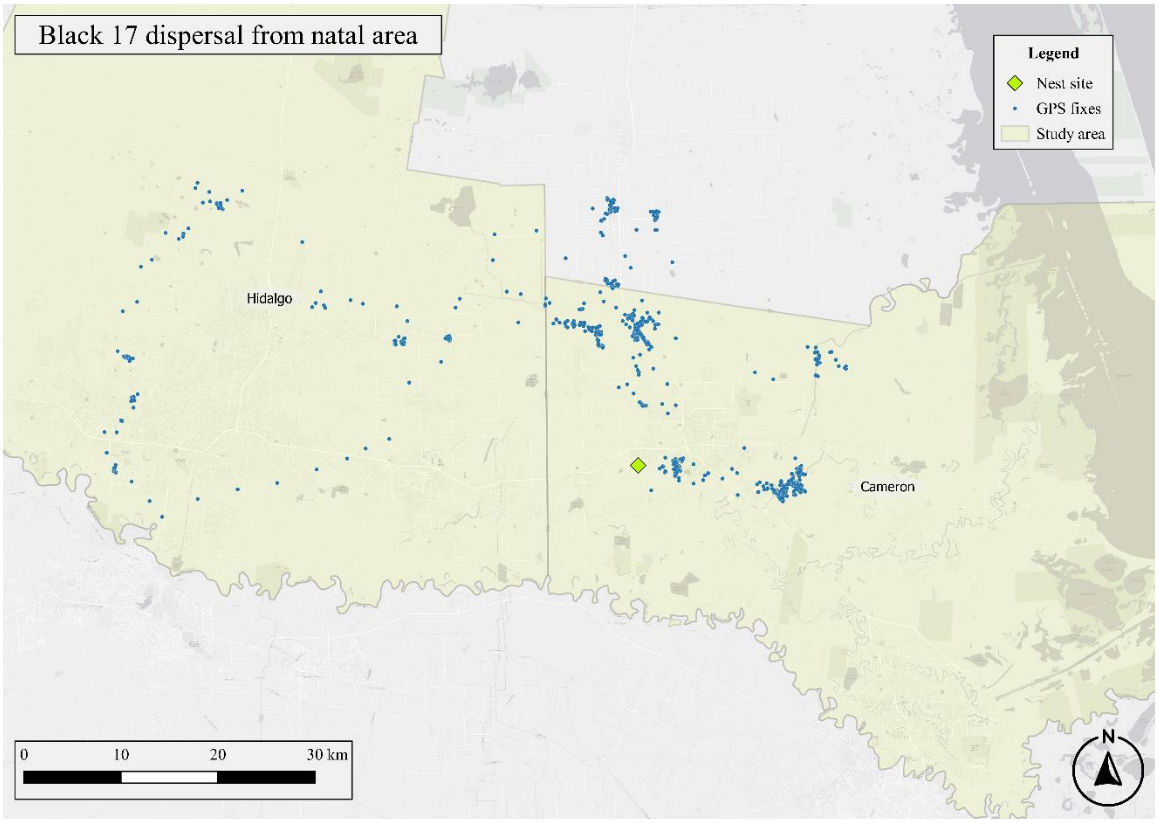
Williams III, S. O., and D. J. Krueper (2008). The changing status of the Gray Hawk in New Mexico and adjacent areas. Western Birds 39:202-208.

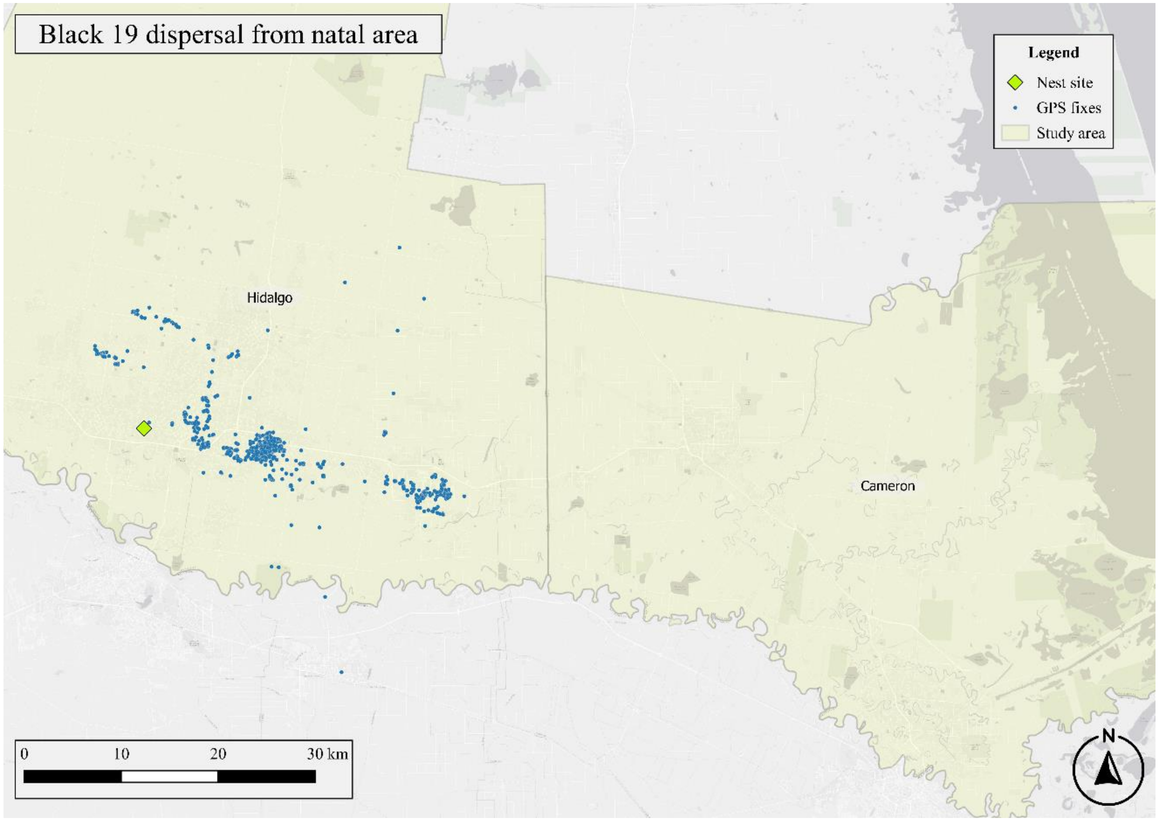
Worton, B. J. (1995). Using Monte Carlo Simulation to Evaluate Kernel-Based Home Range Estimators. Journal Of Wildlife Management 59:794–800

APPENDIX A

APPENDIX A

MAPS SHOWING DISPERSAL PATTERNS OF 14 JUVENILES

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GPS fixes
Study area
Hidalgo
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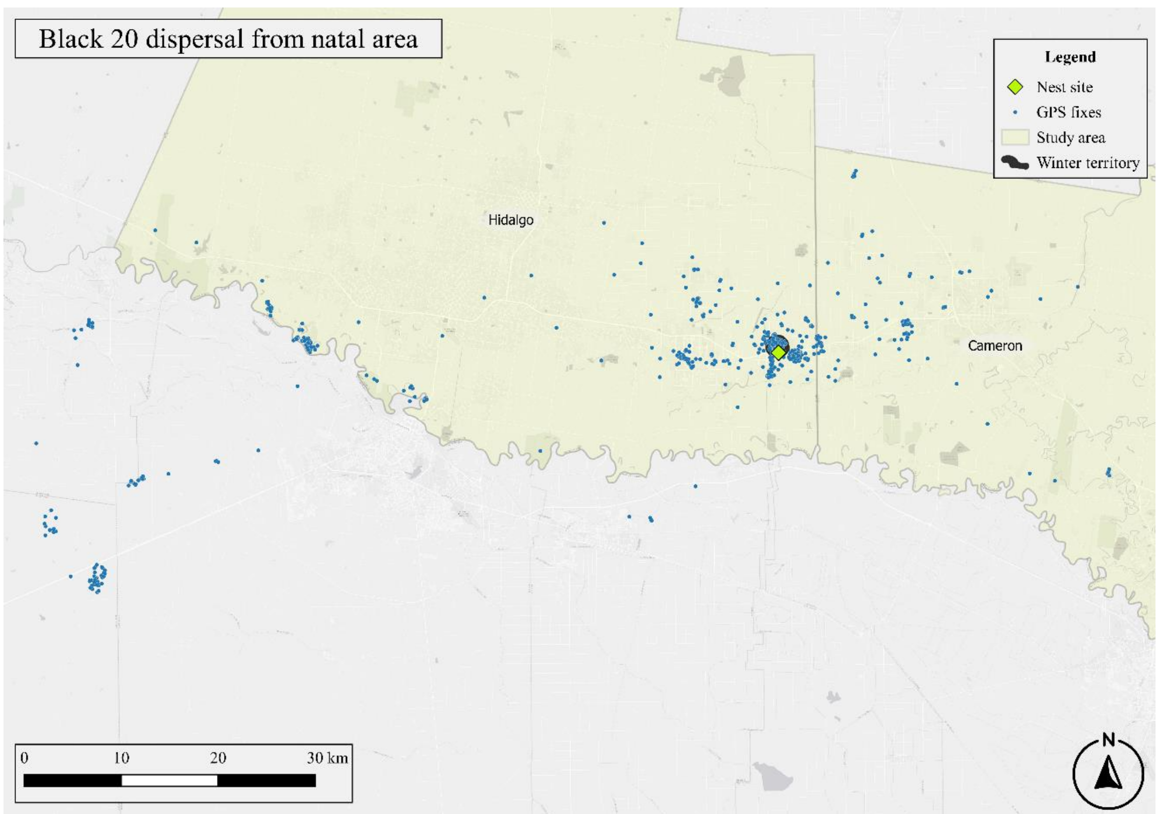
Black 20 dispersal from natal area
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Study area
Winter territory
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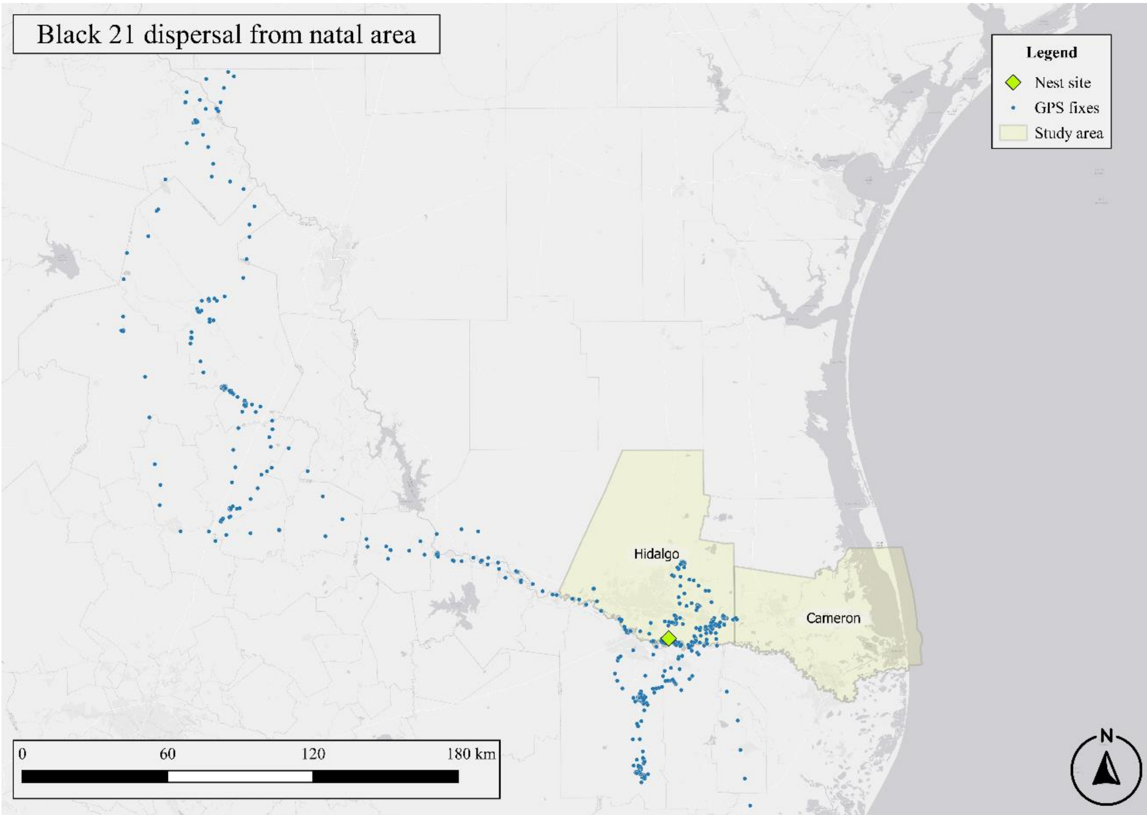
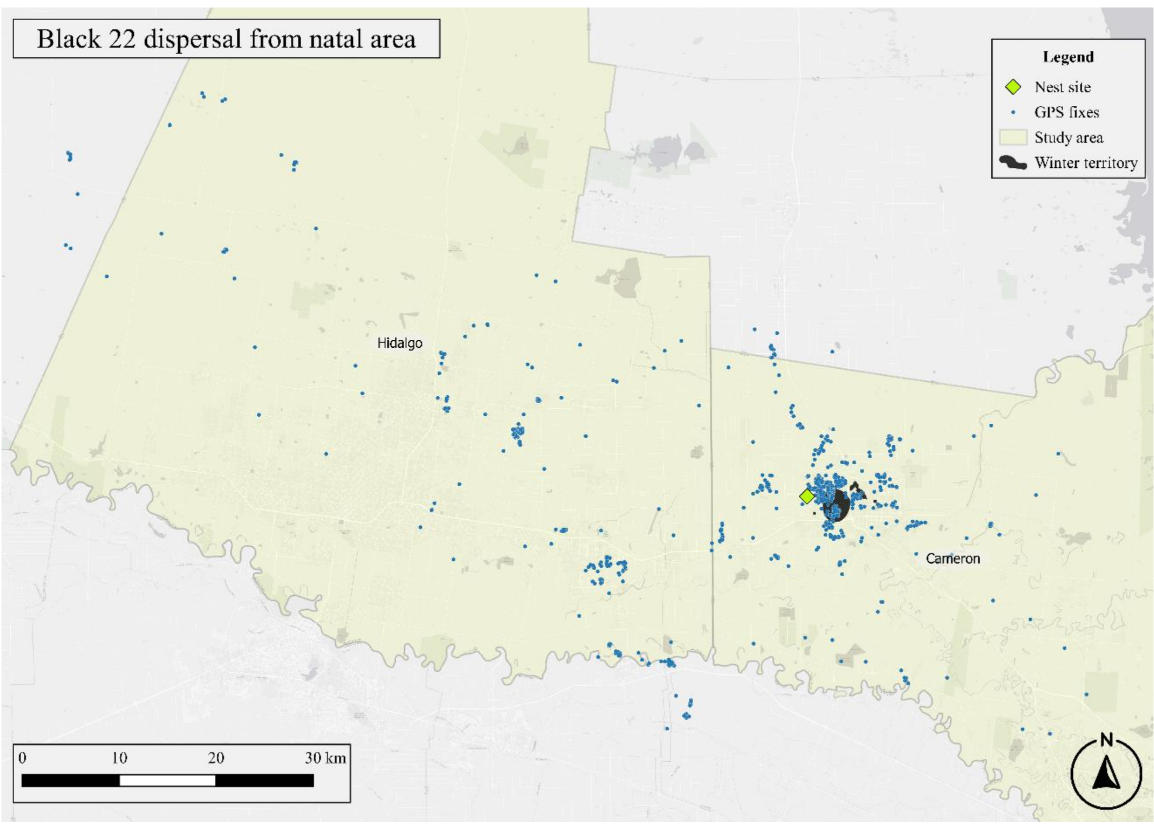


Black 21 dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Hidalgo
Cameron
0
60
120
180 km
N



Black 22 dispersal from natal area
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GPS fixes
Study area
Winter territory
Hidalgo
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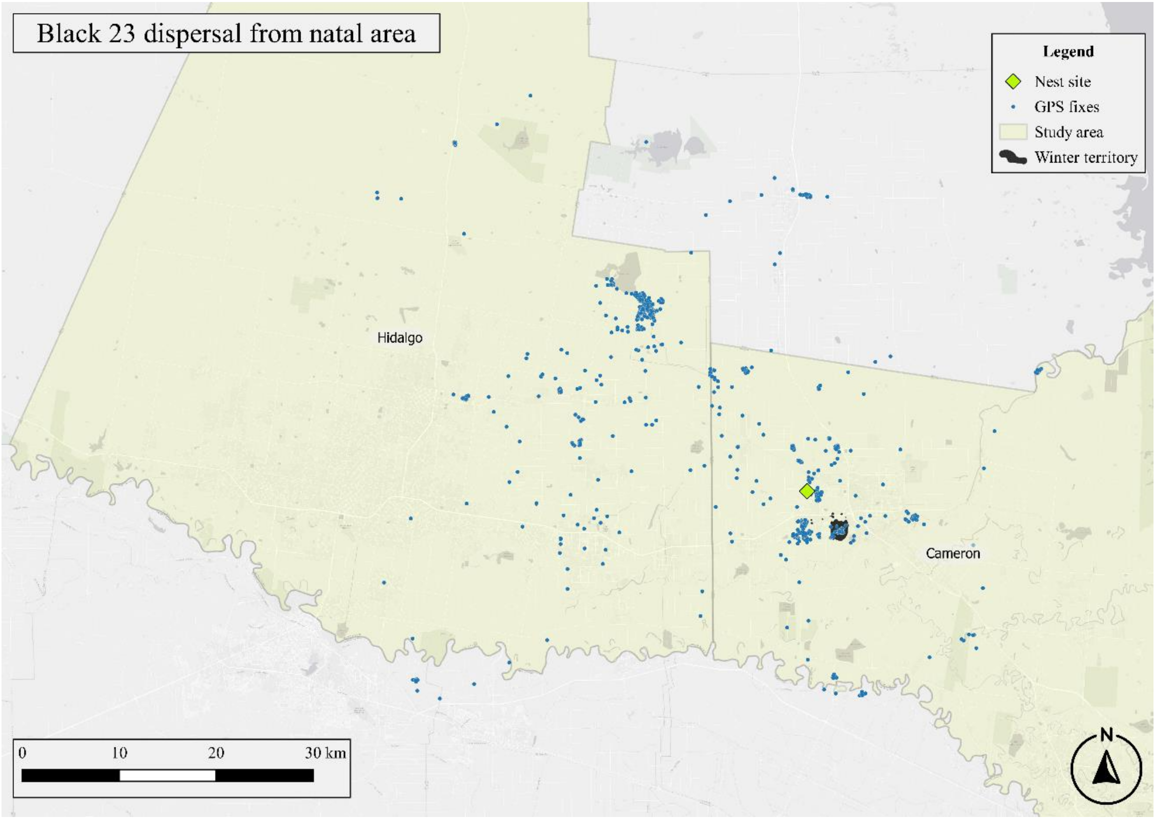
Black 23 dispersal from natal area
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Nest site
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Study area
Winter territory
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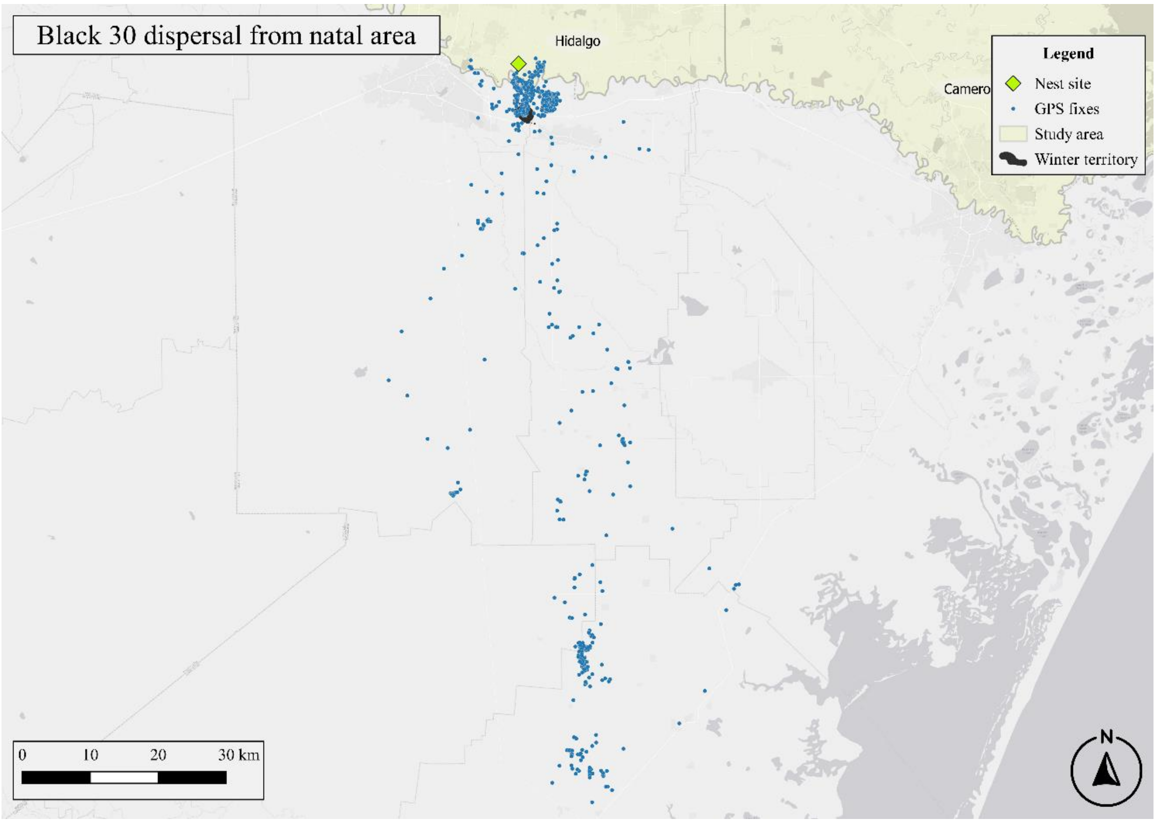
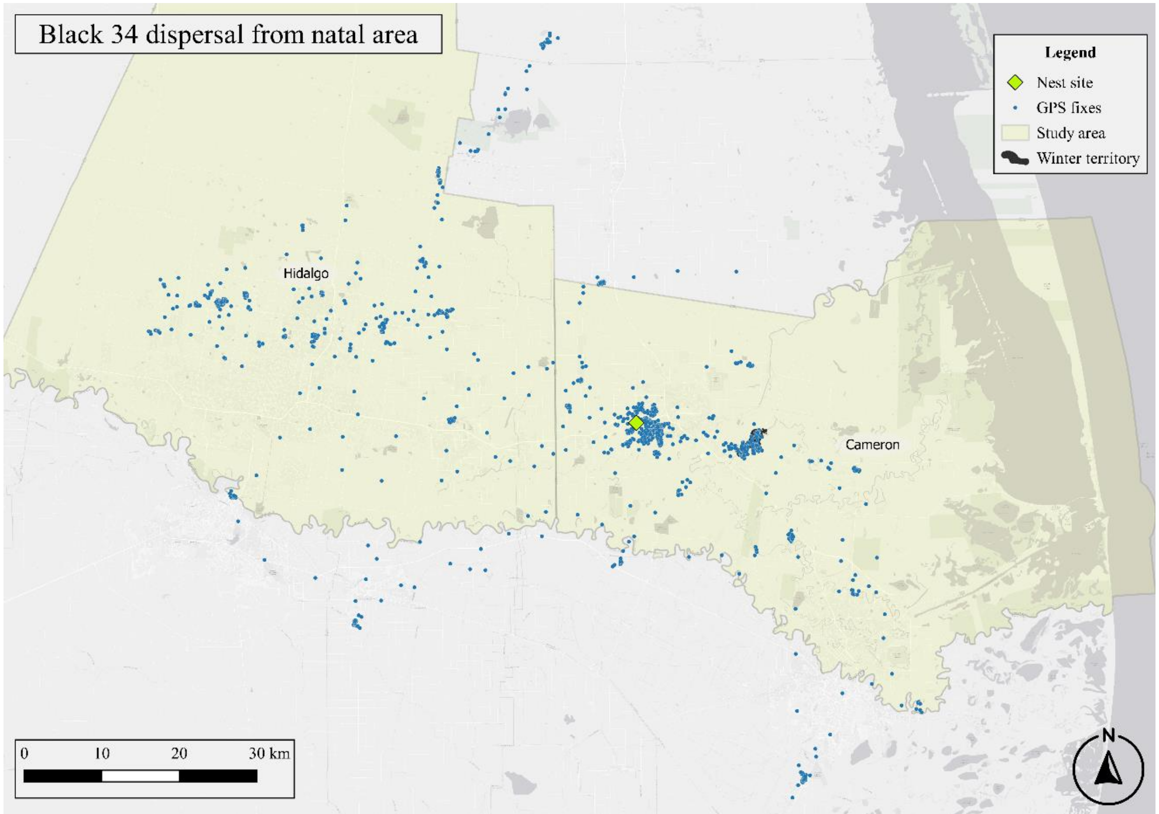
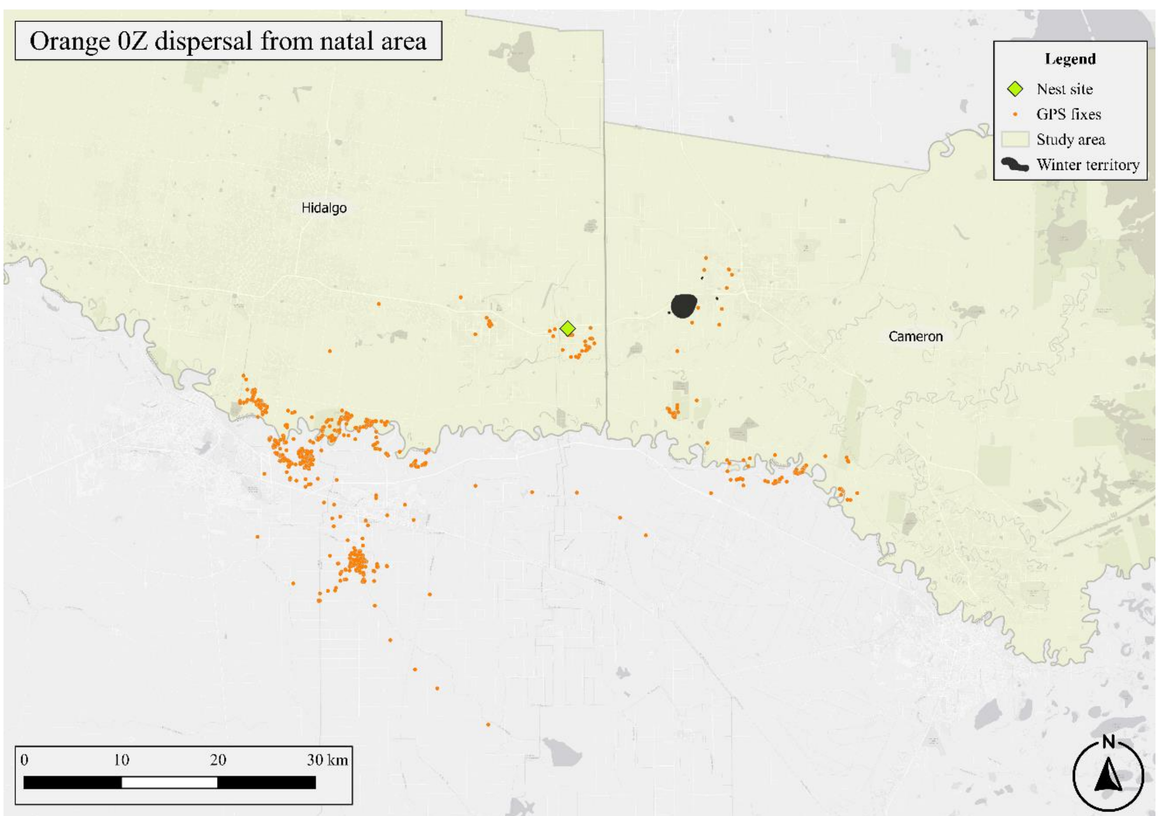
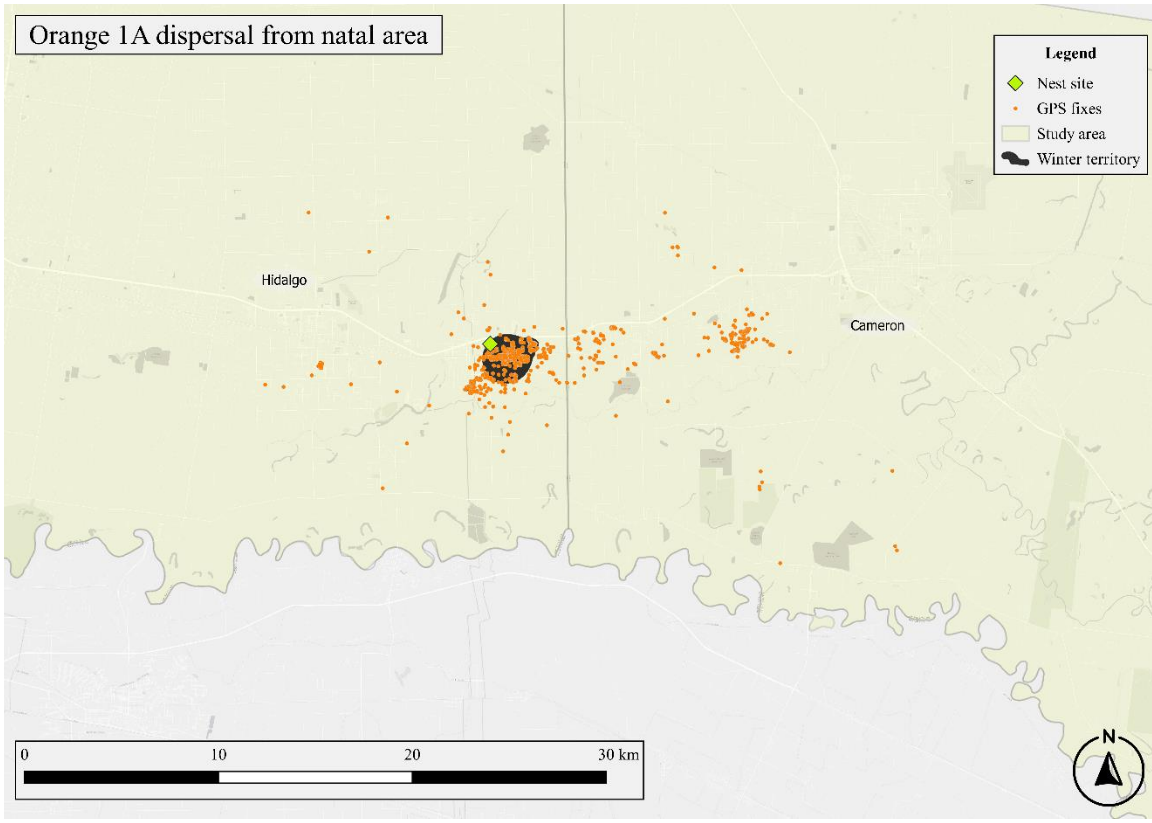
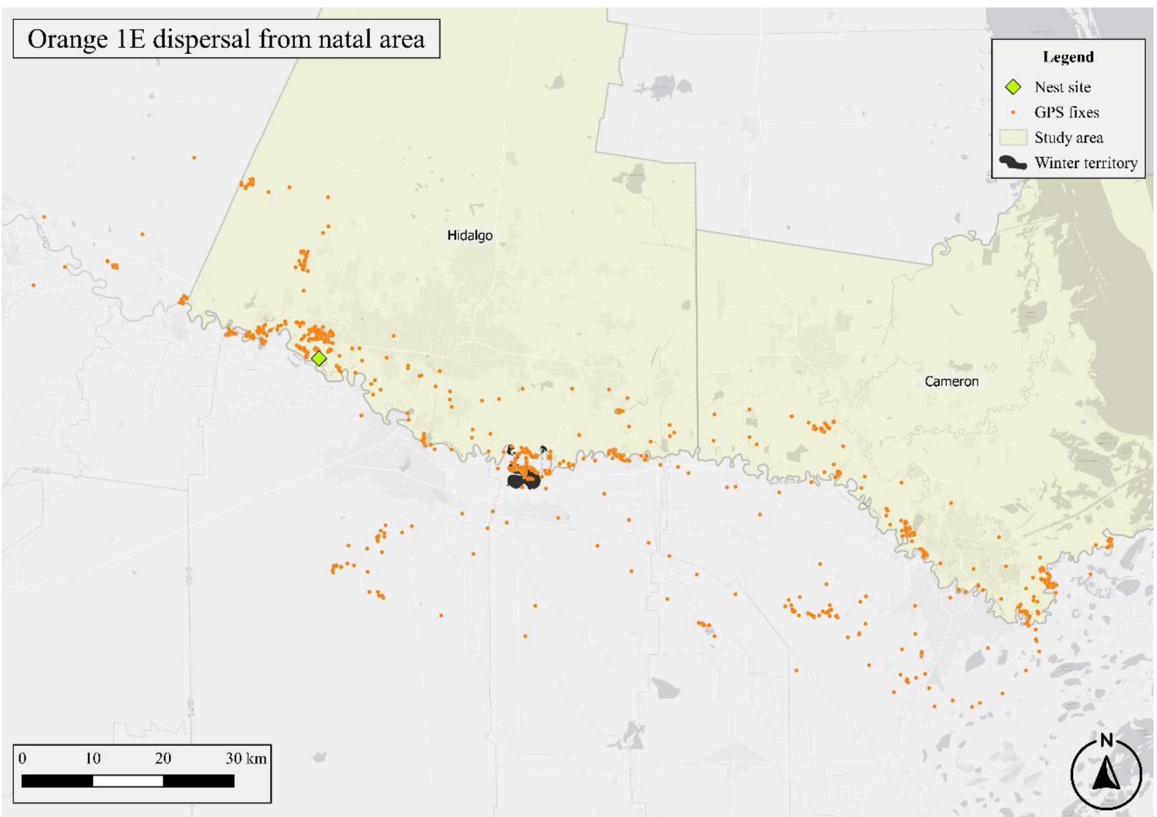
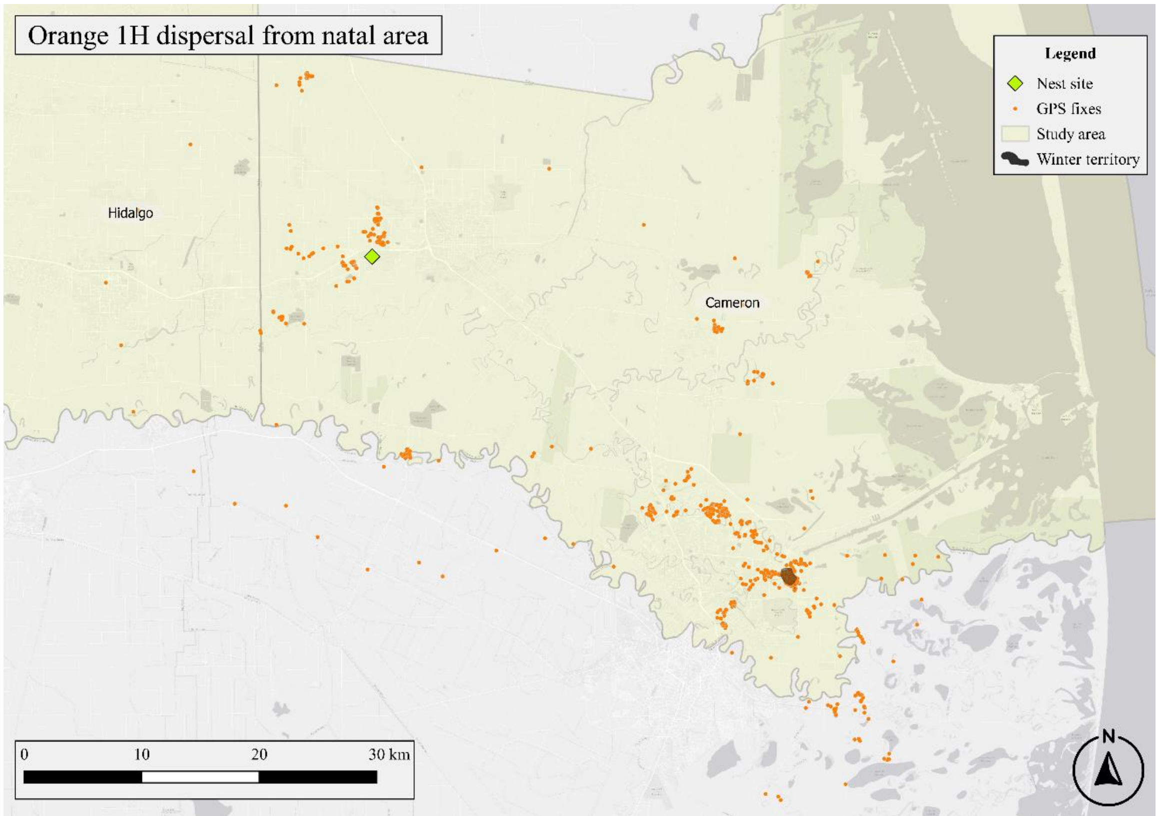

Black 30 dispersal from natal area
Hidalgo
Camero
Legend
Nest site
GPS fixes
Study area
Winter territory
0
10
20
30 km
N

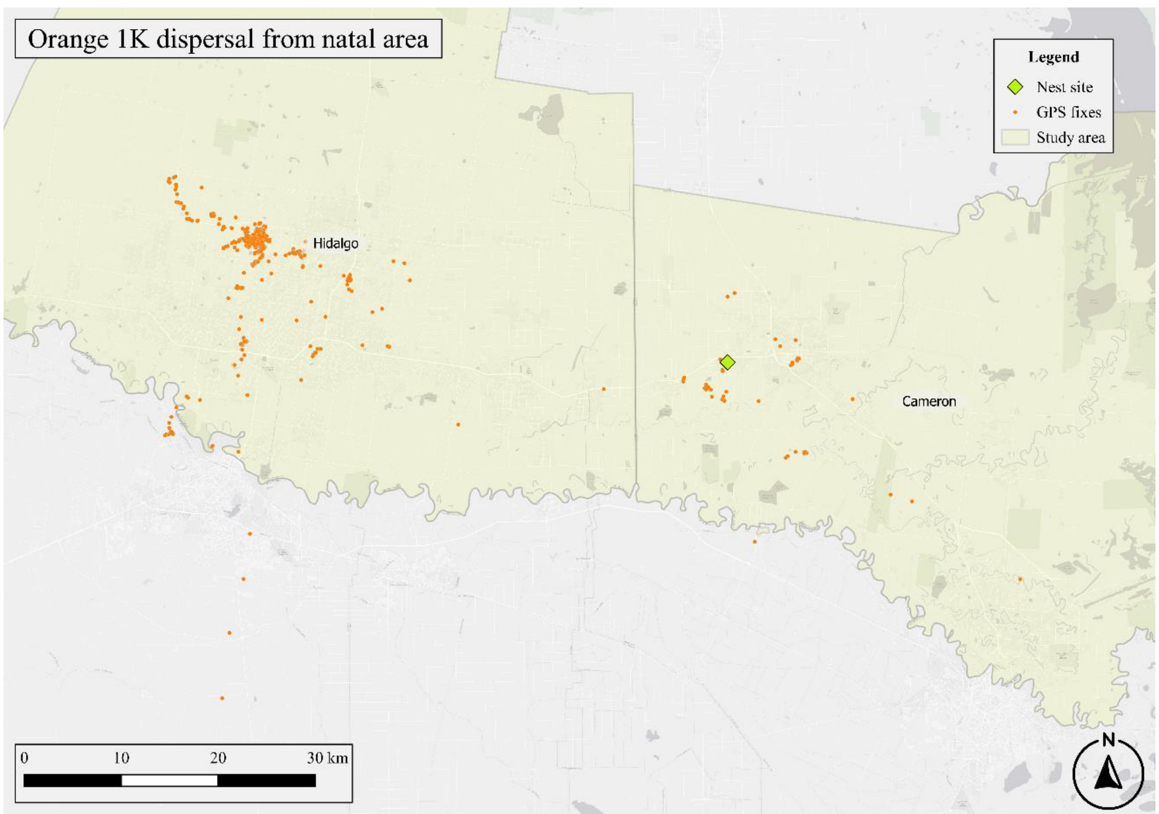

Black 34 dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Winter territory
Hidalgo
Cameron
0
10
20
30 km
N

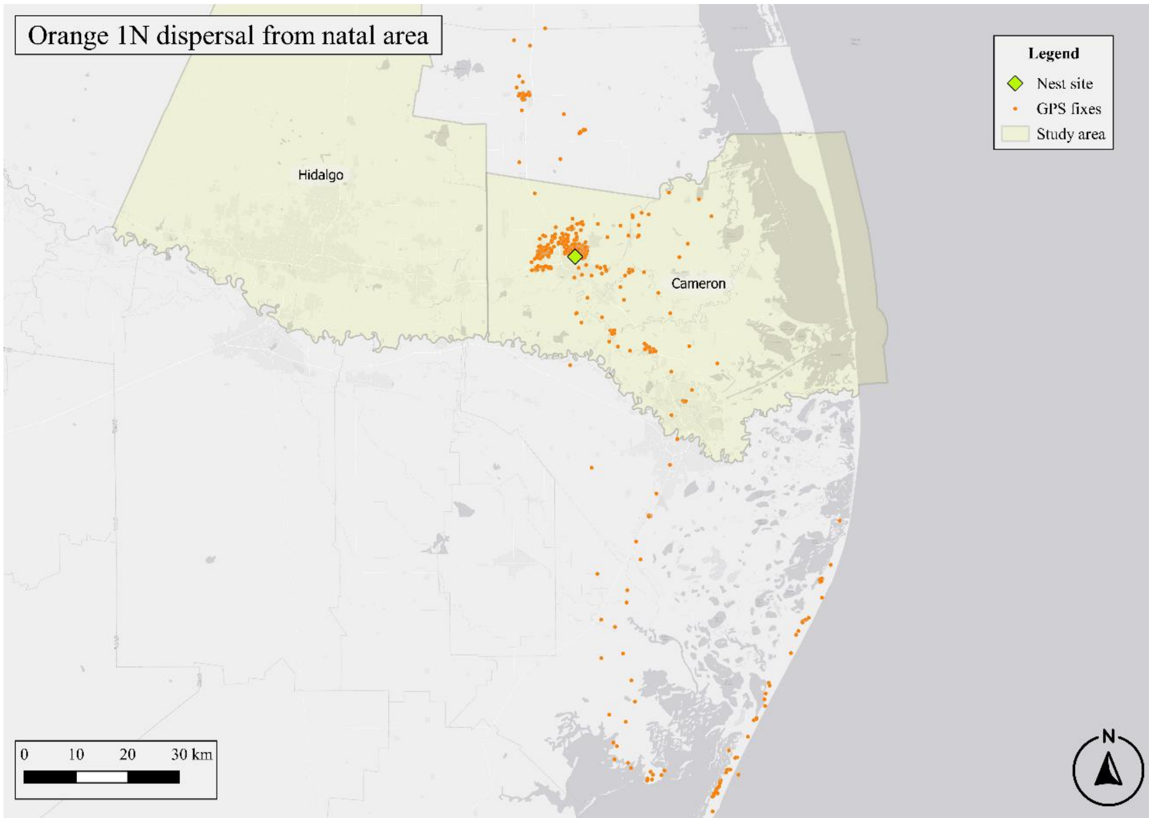

Orange 0Z dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Winter territory
Hidalgo
Cameron
0
10
20
30 km
N


Orange 1A dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Winter territory
Hidalgo
Cameron
0
10
20
30 km
N


Orange 1E dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Winter territory
Hidalgo
Cameron
0
10
20
30 km
N


Orange 1H dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Winter territory
Hidalgo
Cameron
0
10
20
30 km
N


Orange 1K dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Hidalgo
Cameron
0
10
20
30 km
N


Orange 1N dispersal from natal area
Legend
Nest site
GPS fixes
Study area
Hidalgo
Cameron
0
10
20
30 km
N

BIOGRAPHICAL SKETCH

Michael Stewart retired from the military in 2019 after 20 years of service in both the U.S. Navy and the Army. He attended The University of Texas Rio Grande Valley where he conducted research on Gray Hawks and attained a Master of Science in Biology in 2021. Other degrees earned include a Bachelor of Science from Oregon State University in 2015, majoring in Fisheries and Wildlife Science; a Master of Business Administration from Webster University in 2012, a Bachelor of Science in Applied Science and Technology from Thomas Edison State College in 2009, majoring in Nuclear Engineering Technology; and a Bachelor of Science from New School University in 2003, majoring in Human Resources.

Michael plans to continue his research with Gray Hawks while pursuing a Doctor of Philosophy in Wildlife Science at Texas A&M University-Kingsville. His professional affiliations include memberships in the Association of Field Ornithologists, the American Ornithological Society, the Western Bird Banding Association, and the Raptor Research Foundation. In the future he would like to pursue a career as a wildlife biologist working to conserve the avian fauna of North America. He may be reached at a.tristis@gmail.com.