Distributional changes and ecological responses of Harris´s Hawks (*Parabuteo unicinctus*) in Lima city, Peru

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ABSTRACT

Once a rare species in the Peruvian central coast, Harris´s Hawks (*Parabuteo unicinctus*) are becoming one of the most common diurnal raptors in urban Lima. I measured the changes in the species´ home range (95% kernel density estimator -KDE) and identified core areas (50% KDE) in urban Lima from 1985 to 2017. Data was generated by citizen scientists and was available from eBird (www.ebird.org). In all, I obtained 1029 records for the species in urban Lima. Home range of Harris´s Hawks expanded from the city centre (districts of San Isidro and Chorrillos), colonizing heavily populated districts (i. e., La Molina, Pachacamac, Cieneguilla and Santa Eulalia) east and south. However, from 2012 to 2017 home range almost halved. I identified two core areas in the central part of urban Lima that remained constant with time. I argue that the abundance of food and nesting sites in Lima city and the similarity of urban landscapes to foraging and breeding habitats of the species along its range promotes its abundance in heavily populated districts. Given the increased encounters of this medium-sized raptor with humans, it is urgent to implement education programs to reduce persecution and killing of Harris's Hawks in urban Lima.

KEY WORDS: Colonization, kernel distribution estimator, raptors, urban landscapes.

RESUMEN

El Gavilán Acanelado era raro en la costa central de Perú, pero hoy es una de las rapaces diurnas más comunes en la ciudad de Lima. Medí los cambios en el rango hogareño de la especie (95% del estimado de densidad de kernel -KDE) e identifiqué áreas núcleo (50% KDE) en la zona urbana de Lima, desde 1985 hasta el 2017. La información fue generada por científicos ciudadanos y fue obtenida de eBird (www.ebird.org). En total, obtuve 1029 registros de la especie en la zona urbana de Lima. El rango hogareño del Gavilán Acanelado se expandió desde el centro de la ciudad (distritos de San Isidro y Chorrillos), hacia el este y sur, colonizando distritos densamente poblados (La Molina, Pachacamac, Cieneguilla y Santa Eulalia). Sin embargo, entre el 2012 y el 2017, el rango hogareño de la especie se redujo a la mitad. Identifiqué dos áreas núcleo en el centro de la ciudad que permanecieron constantes con el tiempo. Es probable que la abundancia de alimento y de sitios de anidación en la ciudad de Lima y las similitudes de este paisaje humano con los hábitats de alimentación y forrajeo que utiliza la especie en su área de distribución promuevan su abundancia en distritos altamente poblados. Dado el incremento de los contactos entre gavilanes acanelados y pobladores de la ciudad, es necesario desarrollar un programa de educación ambiental que reduzca la persecución directa hacia la especie y la muerte de gavilanes en la zona urbana de Lima.

INTRODUCTION

Bird species responses to urbanization varies. Some dwindle and some benefit as natural habitats are converted into human settlements, and a few can become very abundant (Marzluff 2001). The most important factors that favour bird species in urban areas are increased food and nest availability, and reduced predation (Marzluff 2001, Kendall *et al.* 2017, Suri *et al.* 2017).

Generalist diurnal raptors (Accipitridae) and those that inhabit deserts or savanna-like habitats can take advantage of human settlements as structural complexity of vegetation is usually increased when parks become a common landscape feature in cities and the number of ornamental trees and bushes increase with urban development (Dawson & Mannan 1994, Marzluff 2001, Rullman & Marzluff 2004). However, forest and grassland species are expected to be negatively affected by urban development as this is usually associated with reduced nesting sites (Bosakowsky & Smith 1997; Berry *et al.* 1998).

The Harris´s Hawk (*Parabuteo unicinctus*) is a medium-sized diurnal raptor that inhabit desert scrub and dry deciduous forests from southern North America to central Chile and south Brazil. The species has a broad diet with terrestrial mammals and birds being the most important prey items consumed (Bednarz 1988; Santander *et al.* 2011). All along its range, the species nest in trees and uses upper branches as perches to hunt (Jimenez & Jacksic 1993; Bednarz & Ligon 1988). In western South America, Harris´s Hawks inhabit scrub, savanna and wooded dry forests with sparse tall trees and a relatively open understory (Jimenez & Jacksic 1993; Piana 2015).

Once a rarely seen raptor in the central coast of Peru, nowadays Harris´s Hawks are one of the most frequently seen diurnal raptors in Lima city (Koepcke 1983, Nolazco 2012). Although it is suspected that this population originated from released and escaped individuals that were used for falconry in Lima, young and adult individuals are now frequently seen in parks and groves along avenues and several active nests have been reported here (Nolazco 2012; Piana *et al.* 2013).

The home range of an individual can be defined as the area used for daily activities, including the search for food. The size of this area can be influenced by the species density, and by the sex and age of individuals within a population, and/or by the seasonal changes in the areas where the species occur (Burt 1943; Nielsen *et al.* 2007). Using GPS presence points, kernel methods allow for the estimation of a species probability density function in the area it uses and can inform on their ecological requirements and responses to changes in their distribution. Kernel Density Estimators (KDE) are used to measure species home ranges, and within them, areas with a higher probability of presence (i. e., core areas) can be obtained (Worton 1989, Girard *et al.* 2002, Robinson *et al.* 2012).

In this article I use information collected by citizen scientists that was obtained from eBird (2017) to determine Harris´s Hawks home ranges in urban Lima, Peru between 1985 and 2017, and their changes through time. I also identified core areas used by the species here. This information, and that available for the species in Peru, is later used to explain the expansion of the species home range from heavily urbanized core areas in central Lima to less urbanized areas to the east.

METHODS

I obtained data on the presence of Harris´s Hawks in Lima department (longitude, latitude, locality, effort) from eBird (2017) between January 1985 and December 2017. This data was inspected to remove duplicated records that mainly originated from various observers submitting the same lists and to increase independence of sampling points. To narrow my analysis to urban Lima, I selected records that ranged from Ventanilla and Carabayllo districts in the north to the Punta Hermosa district in the south, and to Santa Eulalia and Cieneguilla districts to the east. Along this study, the area comprised between these districts is referred as urban Lima.

I divided all these records into six time intervals (1985 to 2005, 1985 to 2009, 1985 to 2011, 1985 to 2013, 1985 to 2015 and 1985 to 2017) for analysis. These intervals were selected to obtain at least 24 records per interval, as KDE are sensitive to small sample sizes (Girard *et al.* 2002) and to measure Harris´s Hawk changes in distribution area with time.

I used ArcGis 10.1 (ESRI 2012) to build a shapefile with all records on each time interval and then obtained 95% and 50% kernel density estimators and associated isopleths for each time interval with Geospatial Modelling Environment Version 0.7.2.1 (Beyer 2012) using packages CircStats, deSolve, coda, deldir, igraph, RandomFields and ks, that were installed from R (R core team 2017). Following the recommendations of Beyer (2012), and after inspection of different models, all KDE (Gaussian/bivariate normal) were obtained using the Smoothed Cross Validation (CSV) bandwith estimation algorithm because it showed to produce home ranges that were more relevant to the data I used for analysis. CSV algorithm is a smoothed version of

the Least Squares Cross Validation (LSCV) algorithm that is not sensitive to repeated points (Turlach 1993), a common feature in citizen science reports. The CSV algorithm have been found to perform well in R studio, and, with the data I used, it performed better than the PLUGGIN algorithm. After trying different cell size outputs, I selected a cell size of 0.005 to avoid a blocky output raster that is a poor statistical approximation to a continuous surface (Beyer 2012).

Classification for all 50% KDE were performed in ArcGis 10.1, using the equal intervals classification method and dividing the data into 10 classes expressed as percentages. Later all rasters were converted into shapefiles and plotted into a map with ArcGis 10.1.

RESULTS

I included 1029 Harris´s Hawks records in my analysis. These ranged from 23 records between 1985 to 2005, to 459 from 2016 to 2017. In general, the number of Harris´s Hawks records in urban Lima steadily increased with time, while the area of the 95% KDE increased from 1985 to 2011, and then decreased until 2017.

The largest home range occupied by the species (73 709 ha) occurred from 1985 to 2011. Effort (in minutes) per time interval was highly correlated with number of records at each period (r_s = 1.0; p = 0.003), but area of 95% KDE per time interval was not correlated with effort (r_s = 0.20; p = 0.66), thus home ranges occupied by the species were independent of sampling effort on each time interval. See table 1.

Home ranges of Harris´s Hawks in urban Lima by time intervals are showed in Figure 1. First records of the species were in San Isidro (January 1985) and Chorrillos (June 1996) districts in the central portion of urban

Lima. Between 2006 and 2009, number of record of the species in these districts, and in Miraflores increased, and from this period, the species expanded its home range from San Miguel and Barranco districts, near the coast to the east and south, to La Molina (January 2008), Pachacámac (August 2008) and El Agustino (January 2009) districts. By 2015, areas occupied by Harris´s Hawks east of the city included Cieneguilla and Santa Eulalia, and the western portions of Lurigancho districts. Some individuals were also reported in Ventanilla, to the north and in Lurín to the south. From 2015, most records east were concentrated along the

central highway, in central Lima, and along the road that connects Lurín, Pachacámac and Cieneguilla districts, in the south and east of the city.

I obtained two core areas for Harris´s Hawks in the south and central portions of urban Lima. From 1985 to 2017, the highest concentration of species records remained constant and included the southern portion of Chorrillos district and adjacent Villa El Salvador, to the south, and San Isidro, Lince, Surquillo and Miraflores districts in central Lima (Figure 2).

Period	No. of records	Area 95% KDE (ha)	Effort (min)
1985-2005	23	22006	3710
1985-2009	82	38826	8223
1985-2011	171	73709	8532
1985-2013	311	62752	16997
1985-2015	570	51581	26770
1985-2017	1029	38035	40720

Table 1. Number of records per time interval, area of 95% KDE (in hectares) and search effort (obtained from eBird - www.ebird.org) of Harris´s Hawks registered in the city of Lima, Peru.
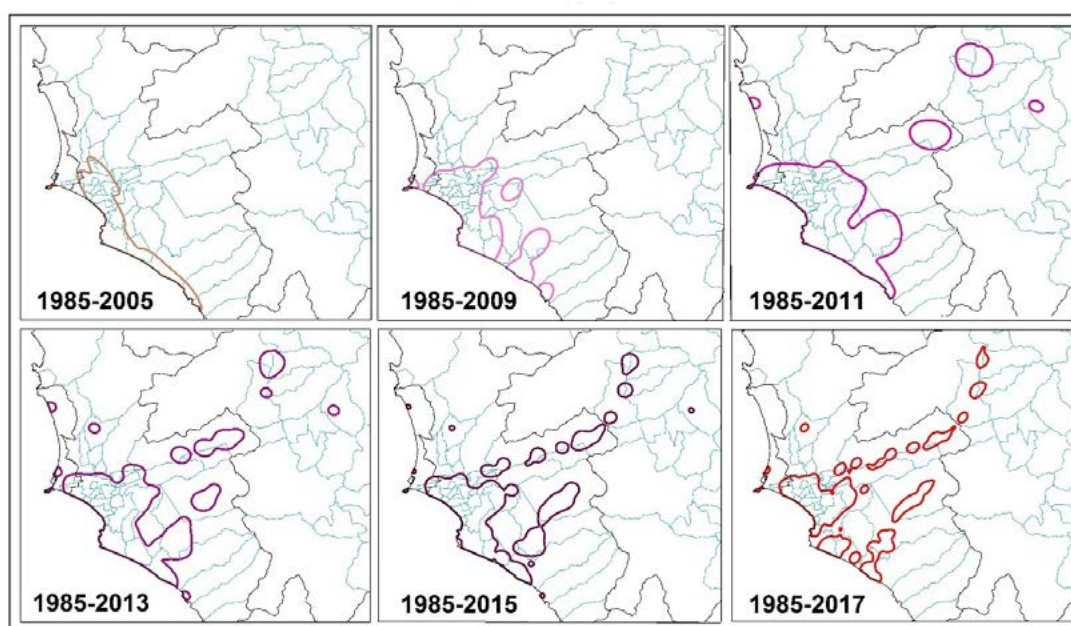
Figure 1. 95% KDE (coloured polygons) of Harris´s Hawks in urban Lima from 1985 to 2017. Limits of districts are shown in blue.
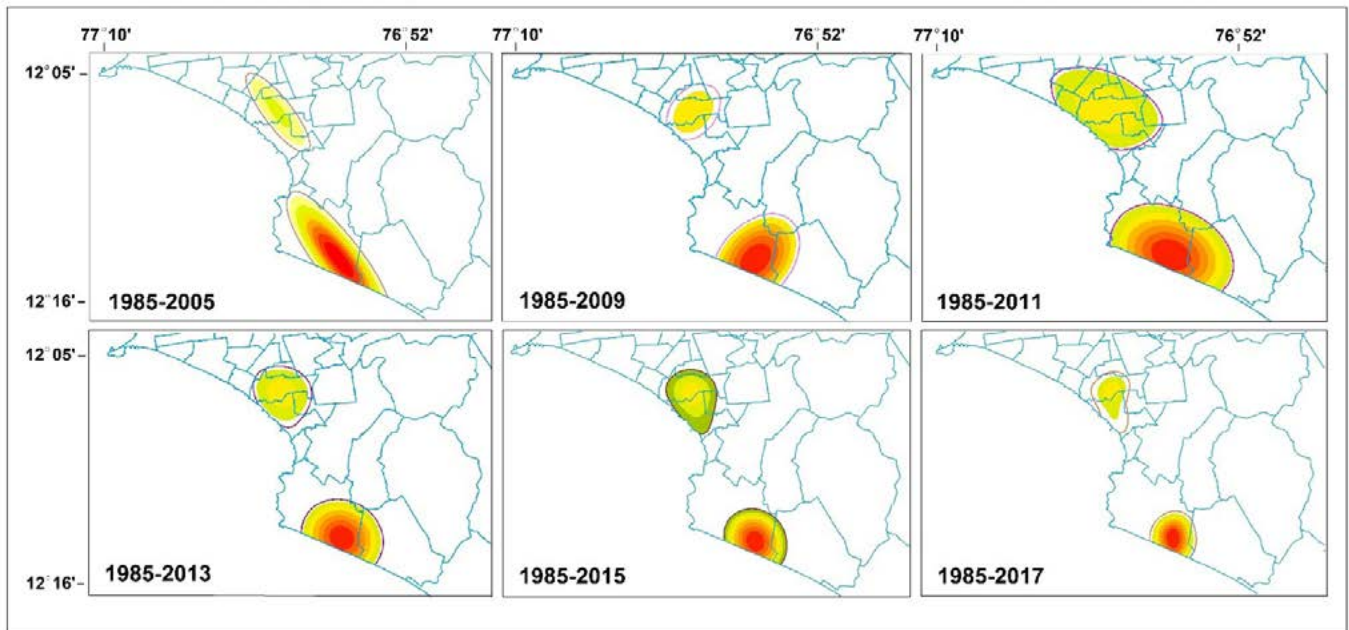
Figure 2. 50% KDE (core area) of Harris´s Hawks in urban Lima from 1985 to 2017. Density of records increased from green/yellow to red areas inside each 50% KDE). Limits of districts are shown in blue.

DISCUSSION

KDE have been used as a measure of home range of species, with the 95% density isopleth producing unbiased and robust home ranges for species with different life histories (Wilson 2010, Orben *et al.* 2018). I selected changes in the area of the 95% density isopleth as a measure of the changes in Harris´s Hawks home range in urban Lima, and the 50% density isopleth as an arbitrary boundary to identify its core area. Although the use of arbitrary isopleths to define a core area can lead to its over estimation, the 50% density isopleth is widely used by ecologists to identify areas highly used by wildlife species, including wide ranging birds (Seaman & Powell 1996; Blundell *et al.* 2001, Wilson 2010, Orben *et al.* 2018). My results show that, from 1985 to 2017 Harris´s Hawks in Lima city expanded its range west and south, but core areas used by the species remained constant, and were located in the centre and south of the city, in heavily urbanized and populated districts that were adjacent to the sea.

Despite Harris´s Hawks being considered highly sensitive to human presence, and although urbanization has been signalled as the main threat for the species in the United States of America (Dawson & Mannan 1994), records in central Lima are mainly from individuals seen on parks and groves along streets in densely populated districts, and most certainly reflect the species ability to use human modified landscapes particularly those that resemble open forests with scattered tall trees that the species prefer for breeding and hunting (Bednarz & Ligon 1988, Jimenez & Jaksic 1993, Piana 2015).

It is a common concern that citizen science data might be influenced by methodological biases such as non-random distribution of counting sites, differences in observers' abilities, and other sources of error that can potentially affect results (Dunn *et al.* 2005). Although it can be argued that my finding are affected by biases derived by increased detection/sampling effort of Harris´s Hawks in areas that are/were more frequented by bird watchers in urban Lima, my results are intended to show the recent origin of

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this species and the temporal changes in distribution patterns of Harris´s Hawks in this city and not changes in population size or abundance. First detection of Harris´s Hawks in popular birding sites in Lima city show that the species was present in the central districts well before than in the periphery.

First detection of Harris´s Hawks in Parque El Olivar in San Isidro was on September 2001, while the first list with more than 10 species for this same site was obtained in September 1997. Likewise, in Miraflores Central Park, Harris´s Hawk was first detected in November 2004, while a list ≥ 10 ten species for this site was obtained in July 1981. However, Harris´s Hawks were first detected in Cieneguilla (pueblo) in May 2010 (first list ≥ 10 species in October 1998), in Santa Eulalia Valley (lowlands) in November 2013 (first list ≥ 10 species in October 1997), and in Pantanos del Callao, it was first registered in October 2013 while the first bird list ≥ 10 ten species was produced in July 2001 (eBird 2017).

Recent records east are from districts crossed by the central highway, and most of them are adjacent to this heavily transited road. Although this is a common route used by birdwatchers during their observation trips to the central Andes (Valqui 2004), vegetation along this highway is dominated by scrub and cacti that resembles the habitat favoured by the species in central Chile (Jimenez & Jaksic 1993, MINAM 2015). An increased number of sightings along this route, and the presence of adult and juvenile individuals here might reflect the expansion of the species home range to the east, instead of being an artefact of an increased number of observers in these areas.

Among the Accipitridae, breeding success and population growth can be influenced by food availability, predation, diseases and availability of adequate nesting sites (Kendall *et al.* 2017, Suri *et al.* 2017). In urban Lima, Harris´s Hawk are known to nest in *Eucaliptus spp.* trees, a large and introduced species that is very common in parks, gardens and streets. A preliminary study of the diet composition of the species in Lima city showed that although the species prey on a diverse array of bird species, most abundant prey items were West-Peruv*ian Dove (Zenaida meloda) and Eared Dove (Zenaida auriculata*), probably two of the most abundant species in the city (Nolazco 2012, Piana *et al.* 2013). Hence, recent population growth of Harris´s Hawks in urban Lima, and its expansion to urbanized districts east could be a consequence of the abundance of food and nesting sites resulting in a high productivity and survival of birds within this urban raptor population, as has been observed in other medium-sized Accipitridae (i. e., Northern Goshawks *Accipiter gentilis* -Rutz 2008, Black Sparrowhawks *Accipiter melanoleucus* -Suri *et al.* 2017, Cooper´s Hawks *Accipiter cooperi* - Mannan *et al.* 2008, and Harris´s Hawks in North America -Dawson and Mannan 1994). It is possible however, that the population in the city is reaching equilibrium and hence the reduction in the species home range from 2012.

In North America, Harris´s Hawks are able to move from undeveloped to urban areas and vice versa (Dawson & Mannan 1994). This study suggests that districts in the centre and south of Lima might be acting as a source for Harris´ Hawks in Lima province, particularly to the east and south of the city. However, as new offspring are forced to settle in peripheral areas, they might occupy areas of less quality (i. e., areas with less suitable nesting trees and/or with low prey density and quality) where productivity and survival will be reduced (Mannan *et al.* 2008). In order to better understand the population dynamics of the Harris´s Hawk

population in urban Lima it is crucial to conduct a study to measure the survival and settlement of individuals through capture (banding) and recapture (resighting) and to evaluate how population growth/decline is related to external conditions such as prey and nesting site availability in these urban-dominated landscapes (Rutz 2008).

As the population of Harris´s Hawks in urban Lima grows, it is expected that human-related wildlife conflicts will arise. Harris´s Hawks might be perceived as a threat to pets and small children as they frequent parks and gardens in densely populated districts. This, in turn, can increase persecution to individuals that might result in their death. As they feed in extremely abundant bird species and rats (*Rattus rattus* - Piana, Pers. Obs.) urban Harris´s Hawks provide an environmental service by preying on species that transmit diseases to humans (Tellez *et al.* 2007). This beneficial role should be highlighted so Harris´s Hawks presence in urban Lima is tolerated and even protected. Because of this, I do caution against the release of imprinted individuals into urban environments since they can develop aggressive behaviours towards humans.

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