Revista Interdisciplinar ANIMUS

INSTITUTO FEDERAL
Mato Grosso
Campus Pontes e Lacerda
Fronteira Oeste

Anthropization and land uses affecting the distribution and abundance of Cathartes aura in Ciego de Ávila, Cuba

Facundo Alvarez
Instituto Antártico Argentino
facualva87@gmail.com

Dennis Denis Ávila
Universidad de La Habana
dennisdenisavila@gmail.com

Lucas Barros da Rosa
Programa de Grande Escala da Biosfera-Atmosfera na Amazônia
lucas.barrosrr@gmail.com

Abstract
Birds of prey are highly selective of habitats. However, the turkey vulture (*Cathartes aura*) has adaptations that allow them to occupy different habitats, with ranges of ~1300 km2. Vulture populations, far from adjusting to random processes, depend on the availability of trophic resources in the different mosaics of the landscape. The "*Gran Humedal del Norte de Ciego de Ávila*" (GHNCA) in Cuba is one of the most important RAMSAR sites at the continental level, constantly threatened by anthropogenic activities. Our objective was to environmentally characterize the different land uses by applying spectral reflectance indices, and to determine their relationship with the abundance and spatial distribution of C. aura within the GHNCA. Vulture abundance and spatial distribution patterns were different between and within each zone considered: abundance data showed different associations with established land uses, suggesting habitat selection. Our results show a strong association of vulture populations with habitats degraded by anthropogenic action within the GHNCA. Despite the species' important ecological role, future anthropogenic interventions may exponentially increase vulture populations, with unpredictable consequences at different spatial and temporal scales in the region.

Key words: home range.raptors.spatial distribution.spectral reflectance indices.Turkey Vultures.

Antropização e usos da terra afetando a distribuição e abundância de Cathartes aura em Ciego de Ávila, Cuba

Resumo
As aves de rapina são altamente seletivas de habitats. No entanto, os urubus-de-cabeça-vermelha (*Cathartes aura*) apresentam adaptações que lhes permitem ocupar diferentes habitats, com áreas de ação de ~1300 km2. As populações de urubus, longe de se ajustarem a processos aleatórios, dependem da disponibilidade de recursos tróficos nos diferentes mosaicos da paisagem. O "*Gran Humedal del Norte de Ciego de Ávila*" (GHNCA) em Cuba é um dos sítios RAMSAR mais importantes a nível continental, constantemente ameaçado pelas atividades antropogênicas. Nosso objetivo foi caracterizar ambientalmente os diferentes usos da terra aplicando índices de reflectância espectral, e determinar sua relação com a abundância e distribuição espacial de C. aura dentro do GHNCA. Os padrões de abundância e distribuição espacial do urubu foram diferentes entre e dentro de cada zona considerada: os dados de abundância mostraram diferentes associações com os usos da terra estabelecidos, sugerindo seleção de habitat. Nossos resultados mostram uma forte associação das populações de urubus com habitats degradados pela ação antropogênica dentro do GHNCA. Apesar do importante papel ecológico da espécie, futuras intervenções antropogênicas podem aumentar exponencialmente as populações de urubus, com consequências imprevisíveis em diferentes escalas espaciais e temporais na região.

Palavras-chaves: área de vida.aves de rapina.distribuição espacial.índices de reflectância espectral.urubus.

INTRODUCTION

Raptors are – in general – highly selective species with respect to the habitats in which they develop (TRYJANOWSKI *et al.*, 2020), presenting ranges of environmental tolerance outside of which they cannot survive (COLEMAN and FRASER 1989; PALOMINO and CARRASCAL, 2007; MONTAÑO-CENTELLAS *et al.*, 2023). This sensitivity is also affected by anthropogenic actions that simplify and homogenize ecosystems, conditioning their demographic and spatial patterns (RODRÍGUEZ-ESTRELLA, 2007; DODGE *et al.* 2014; TRYJANOWSKI *et al.*, 2020). As an exception to this general pattern, Turkey Vultures *Cathartes aura* (LINNAEUS, 1758) have ranges of environmental tolerance that allow them to occupy dissimilar habitats of wide spatial extensions, since their morphological, anatomical and physiological adaptations make a difference compared to other species of raptors (SACCO *et al.*, 2015; KIRK and MOSSMAN, 2020; JOHNSTON and MITCHELL, 2021). Despite their wide home ranges and high abundances, the establishment of Turkey Vulture populations in new habitats is far from adjusting to a random selection process (COLEMAN and FRASER, 1989; MANDEL *et al.*, 2008; TRYJANOWSKI and MORELLI, 2018).

Depending on the spatial scale considered, the environmental and physical factors that can determine the selection of habitats, reproductive output, and the spatiotemporal distribution patterns of raptors are different (FERRER-SÁNCHEZ and RODRÍGUEZ-ESTRELLA, 2015; NÄGELI *et al.*, 2021; MONTAÑO-CENTELLAS *et al.*, 2023). At a macro-geographic scale, the climatic configuration is the main deterministic factor of the richness and abundance of raptors (MELLONE *et al.*, 2012; MONTAÑO-CENTELLAS *et al.*, 2023; PARTRIDGE and GAGNÉ, 2023). On a regional scale, anthropogenic actions and different land uses, together with the level of plant cover, configure environmental and spatial heterogeneity, affecting the availability of foraging and overnight areas (RODRÍGUEZ-ESTRELLA, 2007; TRYJANOWSKI *et al.* 2020). The habitats that Turkey Vultures select do not have specific attributes, varying from densely forested regions to flooded areas with different levels of anthropization and domestic animals' presence (COLEMAN and FRASER, 1989; WALLACE, 2004; TRYJANOWSKI and MORELLI, 2018). However, a factor that denotes greater incidence on the selection of habitats and the spatial distribution of Turkey Vulture is food availability in the different mosaics of the landscape (DODGE *et al.*, 2014; AUGÉ, 2017; BALLEJO *et al.*, 2018, 2021). In case of failing to adapt, Turkey Vulture can simply move to other sites, since this species can be found in any type of land use where it can forage efficiently (DODGE *et al.*, 2014; JOHNSTON and MITCHELL, 2021; PARTRIDGE and GAGNÉ, 2023).

The spectral reflectance indices (SRIs) of satellite images in conjunction with geographic information system (GIS) tools allow researchers to obtain environmental and physical information from large territorial areas regardless of geographical, economic or logistical limits (HUANG *et al.*, 2002; SRUTHI and ASLAM, 2015). The "Gran Humedal del Norte de Ciego de Ávila" (GHNCA), RAMSAR sites, was proposed as an Area of Importance for the Conservation of Birds by Birdlife International, and it has seven protected areas of which three are classified as Wildlife Refuges (STATTERSFIELD and CAPPER, 2000; FERRER-SÁNCHEZ and RODRÍGUEZ-ESTRELLA, 2021). However, in recent decades, Cuba and the cay areas had an increase in tourist activities, especially after the GHNCA was identified as an area with potential for tourist exploitation, compromising the different regional bird communities (FERRER-SÁNCHEZ and RODRÍGUEZ-ESTRELLA, 2015; 2021).

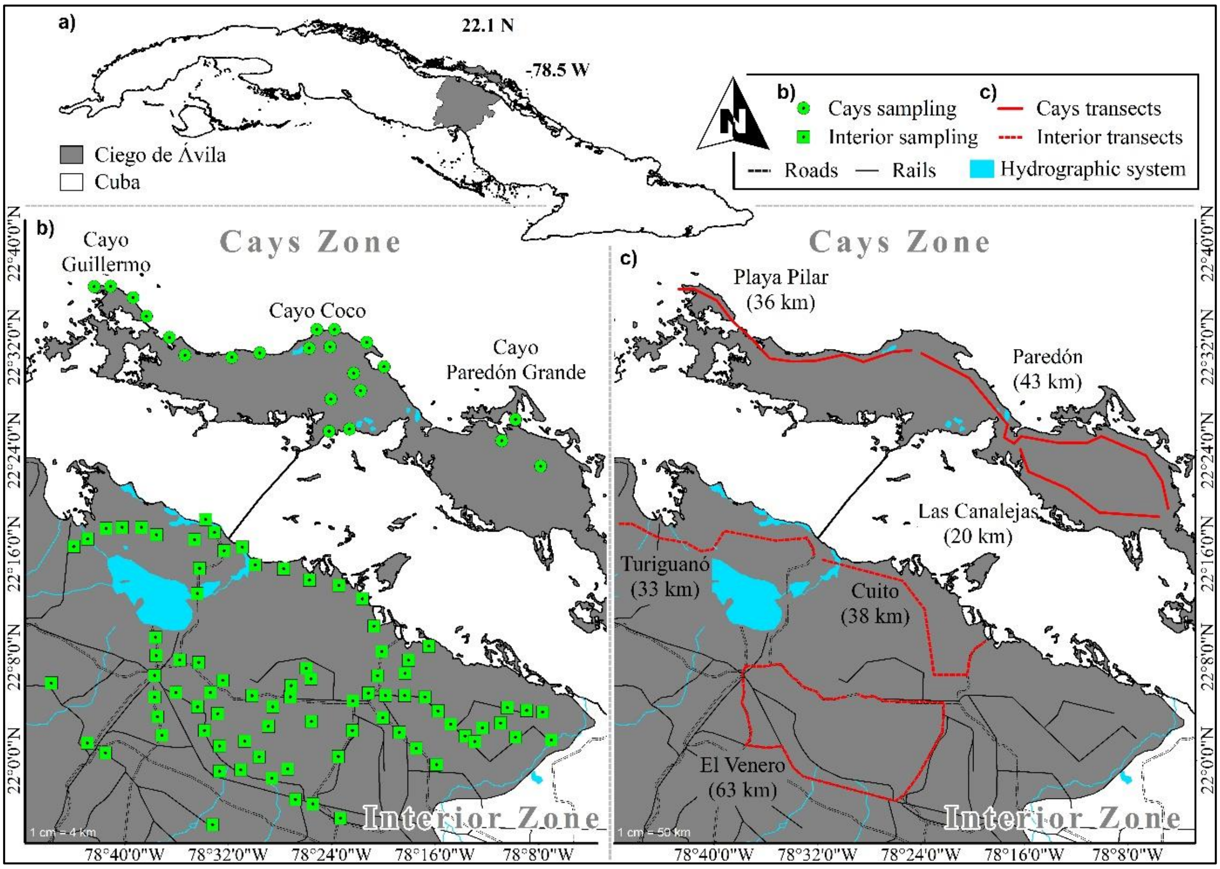
Turkey Vultures, like other vultures, play a key role in ecosystems acting as indicators of environmental pollution, increasing decomposition rates, eliminating possible infectious foci, and articulating nutrient cycles, among others (RAMSDEN, 1916; MORELLI *et al.*, 2015; BALLEJO *et al.*, 2021). Despite this, the studies conducted in Cuba with this species are scarce and ancient, mostly oriented to general ecological characteristics (e.g., RAMSDEN, 1916; WOTZKOW and WILEY, 1988; TRYJANOWSKI and MORELLI, 2018). In this study, we focused on the Wallaceana knowledge gap, where spatial patterns of geographic distribution are unknown or scarce for the focus species (HORTAL *et al.*, 2015). The objective was to characterize the different land uses, by applying SRI, and determine their relationship with the relative abundance and spatial distribution of Turkey Vulture inside the GHNCA, Cuba.

MATERIALS AND METHODS

Study Area

We develop the work within an area of ~5,000 km2 in the central region of Cuba, encompassing the northern cays system of the province of Ciego de Ávila and its interior zone (Fig. 1). Included within the study area is the GHNCA, a coastal-type wetland that is part of the largest hydrographic basin in the province (La Yana basin). Between the cays areas and the interior of this study area there is a discontinuity space, the "Bahía de Los Perros.

Fig. 1: Geographic location of the GHNCA within the province of Ciego de Ávila, Cuba (a) and geographic delimitation of the interior zone on the North coast of Ciego de Ávila (b) and the cays zone (c). Sampling stations and transects distributed within the interior zone (green squares and dashed red lines, respectively) and within the cays zone (green circles and solid red lines, respectively)



In the cays zone of the GHNCA, the flood regime is permanent and with low variation, with annual rainfall of ~875 mm, while in the interior zone the annual rainfall is 1,243 mm (Brown-Manrique et al. 2017). On the other hand, regional temperatures fluctuate between 20 and 30° C (MENÉNDEZ PÉREZ *et al.*, 2011). In the interior zone, La Loma de Cunagua stands out as the highest elevation, in contrast to the zone of cays, which is characterized by a low, cumulative-abrasive coastal plain (BENNETT and ALLISON, 1928). The flora of the cays zone is characterized by communities of xeromorphic shrubs, deciduous forests and evergreen microphyllous, halophytic vegetation and vegetation associated with rocky and sandy substratum (MENÉNDEZ PÉREZ *et al.*, 2011). The interior zone is made up of communities of evergreen forests, secondary forests, swampy meadows, deciduous forests and different agricultural crops (RICARDO *et al.*, 2009). Within the mosaic of landscapes, we considered forests, mangroves, salt ponds and grasslands as natural areas, while farmlands and other anthropized landscapes (buildings and infrastructure) were considered as modified areas.

Surveys on Turkey Vultures

We carried out the surveys on Turkey Vultures following two methods: simultaneous fixed points and road transects with vehicles. We randomly selected 111 fixed sampling stations within both regions, with 24 stations in the cays zone and 87 in the interior zone. We randomly chose the stations within each zone by computerized lottery and selected those points with easy logistics and access for sampling. We conduct censuses at these stations in 2010 and 2012, in the morning from 09h30 to 12h00 and in the afternoon from 16h00 to 19h00. We sample the fixed stations in one-hour intervals and we resampled all the points without exception in both 2010 and 2012.

Also, we established six transects in each zone, totaling 233 km within the GHNCA. We traveled these transects using various means of transport at a constant speed of 20-30 km/h, in the months of April, July and November (2007), and February, April and October (2008). We also carry out censuses during the morning (08h00 to 12h30) and the afternoon (16h00 to 19h00). We estimate the relative abundance in occurrences/hour (OCC/h), with the censuses being carried out simultaneously in at least three monitoring points, to minimize possible repeated occurrences. Due to the logistical difficulties inherent in the work area, we did not carry out the censuses in a spatially or temporally homogeneous way. In this sense, we carry out two to three transects per day and as many fixed points as possible, both during the morning and in the afternoon. We carry out the censuses in different work teams, one team carried out the censuses along the transects and another team carried out the samplings at the fixed points.

Environmental and physical variables

We use two groups of environmental and physical predictors, one of spectral character (satellite telemetry) and another of Euclidean distances, in order to establish probable relationships of the species with the land uses. We calculated the Euclidean distances (in km) from the GPS points of occurrence of Turkey Vultures to coasts, towns, roads and water bodies from the use of digitized vector maps with a scale of 1:50 000. From these vector maps we estimate the territorial extension of the key and interior areas (in km2) to later calculate the probabilities of the presence of Turkey Vultures in each one of them.

We calculated and extracted the spectral character variables using the SRI referred to the surface temperature, surface humidity and the Normalized Difference Vegetation Index (NDVI). We used a multi-spectral satellite image in FAST format for 2011, from the Landsat 7 ETM+ (trajectory 13/row 44), and we extracted the images from the USGS platform (https://usgs.gov). We obtained these images already adjusted radiometrically and geometrically, referenced in UTM-17 projection (datum WGS84). We calculated the surface temperature from the thermal infrared band (6H), with the conversion of digital levels to radiance and the subsequent obtaining of the brightness temperature by means of the inversion of the Planck equation, this allows researchers to estimate the temperature with an error of approximately 0.22° C (Sobrino et al. 2004). We calculated humidity from the 'wetness' spectral index of the 'Tasseled Cap' transformation on the Landsat basic bands (Huang et al. 2002). We use the NDVI to characterize the vegetation cover, we calculated it from the difference between the reflectance of bands 4 (near infrared) and 3 (visible - red) divided by the sum of these two bands of reflectance. We do all the processing related to the Landsat 7 satellite image and the SRIs was carried out using the QGIS software [version 3.14; Quantum GIS (Geographic Information System) QGIS.org, 2020].

We performed the supervised satellite image classification by the maximum likelihood method, which allowed us to represent the main habitats of the study area. We defined the classes as vegetal formations (forests, mangroves, grasslands and farmlands), salt ponds and anthropogenic areas. To evaluate these classifications, we made a matrix of confusion based on randomly distributed points in the study area, and the verification of the classes was performed through field visits and visual interpretation.

Data analysis

The great extension of the GHNCA presents a spatial discontinuity (the Bahía de los Perros) which, together with the spatial, environmental and biotic heterogeneity, configures the landscape differently. For this reason, we analyzed this study area separately, so we applied two ways of spatial analysis for the occurrences of Turkey Vultures, both in the interior zone and in the cays zone. In the first way, we created the Regions of Interest (ROI) from the maximum spatial resolution of Landsat 7 (30x30 m). This local scale acted as a proxy to represent the presence/absence data of the species. On the second way, we created 3x3 km ROIs of spatial resolution to represent the geographic distributions of relative abundances on a regional scale.

We calculated, for each zone, the descriptive statistics for the relative Euclidean distance data and for the data of the environmental variables obtained from the SRIs, which characterized and defined the land use in each zone. We processed the abundance data separately, dividing the process between the cays zone and the interior zone. In this sense, we compared the environmental variables defined by the SRIs and the relative abundances for each zone using the Mann-Whitney U test (MCKNIGHT and NAJAB, 2010). To compare the relative abundance values of each zone between types of land use, we used a Kruskal-Wallis test (MCKNIGHT and NAJAB, 2010) and to compare the spectral values of each SRIs at these zones we applied the Student "t" test. With software QGIS we applied the KDE (Kernel Density Estimation) function to improve the visual interpretation of the spatial distributions of the abundances of Turkey Vulture within each zone.

RESULTS

Predictor variables and land uses

The digital processing of SRIs allowed generating three thematic maps with their respective frequency histograms, to spatially represent surface temperature, surface moisture and NDVI within the GHNCA. The average temperature was not different between zones, with 25.07 °C in the zone of cays and 25.44 °C in the interior zone. However, the maximum temperature values were associated with different land uses: salt ponds within the cays zone and farmlands in the interior zone (Tab. 1).

Tab. 1: Descriptive statistics of the environmental variables for each type of land uses considered within the GHNCA, Cuba (SE: Standard Error, CL: Confidence Limit).

Zone	*Land uses*	*Environmental variables*	*Mean*	*SE*	*CL (95%)*	*Min.*	*Max.*
Cays	Forests (N=7)	Temperature	24.40	0.49	23.54 - 25.95	22.22	26.25
		NDVI	0.49	0.02	0.42 - 0.56	0.41	0.61
		Humidity	61.70	1.61	57.76 - 65.66	54.00	67.00
	Mangroves (N=10)	Temperature	24.70	0.60	23.32 - 26.05	20.67	26.74
		NDVI	0.17	0.07	-0.03 - 0.35	-0.42	0.36
		Humidity	61.00	2.78	54.70 - 67.30	48.00	80.00
	Salt ponds (N=7)	Temperature	26.10	0.85	23.99 - 28.17	23.74	28.71
		NDVI	-0.01	0.08	-0.20 - 0.18	-0.31	0.21
		Humidity	58.60	6.27	43.21 - 73.92	39.00	79.00
Interior	Forests (N=15)	Temperature	25.40	0.31	24.78 - 26.03	23.23	28.70
		NDVI	0.30	0.04	0.23 - 0.42	-0.01	0.85
		Humidity	65.30	1.27	62.63 - 7.89	52.00	74.00
	Mangroves (N=8)	Temperature	25.10	0.22	24.69 - 25.61	22.72	27.72
		NDVI	0.20	0.03	0.19 - 0.31	-0.01	0.53
		Humidity	68.10	1.00	65.90 - 70.15	59.00	78.00
	Anthropic (N=8)	Temperature	25.40	0.30	24.78 - 26.03	23.23	28.70
		NDVI	0.30	0.05	0.23 - 0.42	-0.01	0.85
		Humidity	65.30	1.27	62.63 - 67.89	52.00	74.00
	Farmland (N=38)	Temperature	27.20	0.18	26.84 - 27.60	24.25	30.15
		NDVI	0.10	0.02	0.10 - 0.17	-0.02	0.40
		Humidity	59.90	0.61	58.73 - 61.29	52.00	70.00
	Grassland (N=18)	Temperature	25.10	0.22	24.69 - 25.61	22.72	27.72
		NDVI	0.20	0.03	0.19 - 0.31	-0.01	0.53
		Humidity	68.07	1.01	65.99 - 70.15	59.00	78.00

The spatial simplification and landscape homogeneity of both categories can explain these results; the physical characteristics of reflectance of these open surfaces and with little or no vegetal cover, can increase the temperature of the immediate atmosphere. The highest values of NDVI were associated with forests, both in the cays and in the interior zone, and the lowest values were obtained in the salt flat ecosystems of the cays and in the farmlands of the interior zone. Although the proportions and spatial extensions of each land use were different in each zone, these results may be a partial proxy of the floristic configuration and the potential degradation status of each zone. Finally, we obtained the highest humidity values in the forests and mangrove ecosystems of the cays zone. Both categories present lower thermal reflectance and higher relative values of NDVI, these physical characteristics and the state of the vegetation can condition the higher values obtained for humidity. The relative distances differed between both zones (Tab. 2). For the zone of cays, the values of average distance to water bodies was high (6.08 ± 1.39), but not their average distances to the coast (0.74 ± 0.19). However, the interior zone presented a higher proportion of water bodies, therefore their average distances were lower (2.44 ± 0.24).

Tab. 2: Descriptive statistics of the relative abundances of Turkey Vultures according to the zone and the type of habitat considered within the GHNCA (N: Number of observations, SE: Standard Error, CL: Confidence Limit, CV: Coefficient of Variation).

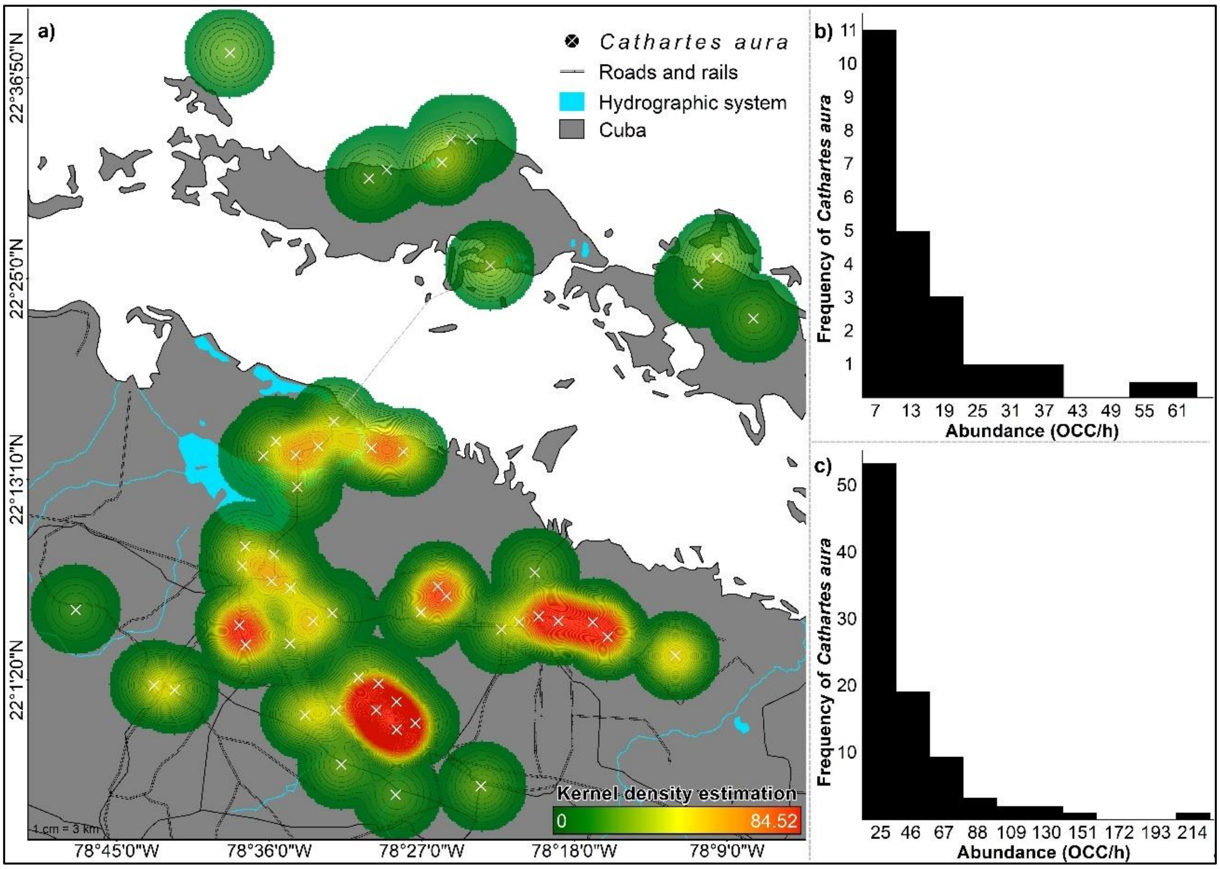
Zone	*Relative distances (Km)*	*N*	*Mean*	*SE*	*CL (95%)*	*CV*
Cays (n=24)	to coast	24	0.74	0.19	0.34 - 1.14	127.20
	to towns	24	4.88	1.23	2.32 - 7.43	124.00
	to roads	24	3.18	1.25	0.58 - 5.78	193.70
	to bodies of water	24	6.08	1.39	3.20 - 8.96	112.10
Interior (n=87)	to coast	87	13.42	0.99	11.44 - 15.41	69.30
	to towns	87	5.19	0.4	4.40 - 5.99	71.90
	to roads	87	0.54	0.09	0.35 - 0.74	170.90
	to bodies of water	87	2.44	0.24	1.96 - 2.93	93.10

Distribution, abundance and habitat use of Turkey Vultures

We registered a total of 309 spatial occurrences within the study area. The interpolation generated from the Kernel function allowed the identification of different spatial patterns of occurrence for each zone, suggesting possible habitat selection by the species (Fig. 2). Within the cays zone, the highest probability values of presence were associated with the

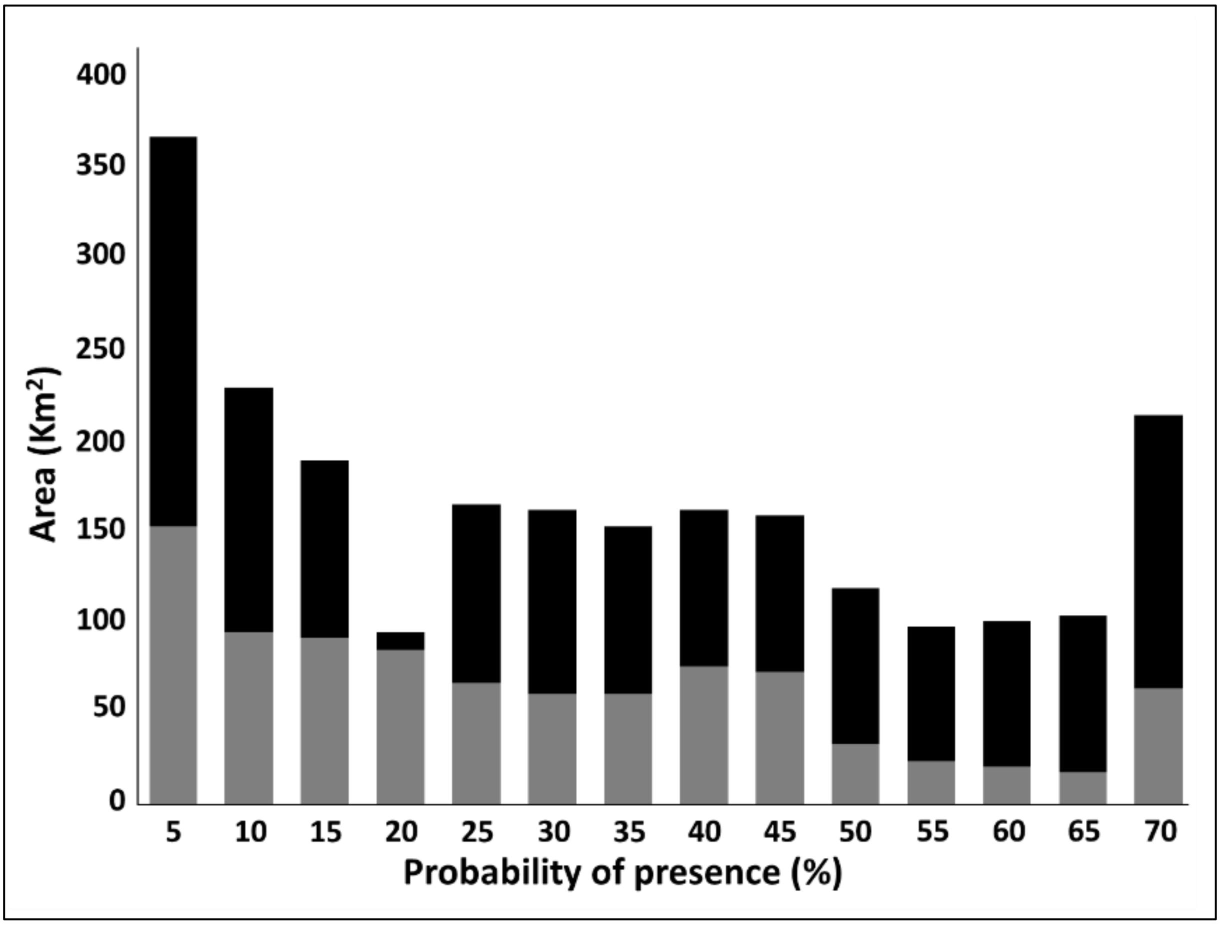
North and South coasts of Cayo Coco, with a diluted gradient towards the South-West. Similarly, in the case of Cayo Guillermo and Cayo Paredón Grande, their North coast and central region presented intermediate values of probability, decreasing towards the South coast (Fig. 2a). In the case of the interior zone, the highest probability values were associated with the vicinity of the localities Turiguanó, Venero-Morón, Monte Malo and in the grassland of the North coast of the province. In contrast, the lowest probability values were associated with the large mangrove forests in the interior zone of the GHNCA (Fig. 2a).

Fig. 2: Distribution of relative abundances (OCC/h) and frequency of observations of Turkey Vultures by survey stations obtained from the Kernel function (a), within the cays (b) and the interior zone (c) of the GHNCA. The color gradient obtained with the Kernel function shows higher abundances (red color) associated with the central region of the interior zone and the lowest abundances (green color) in the cays zone.



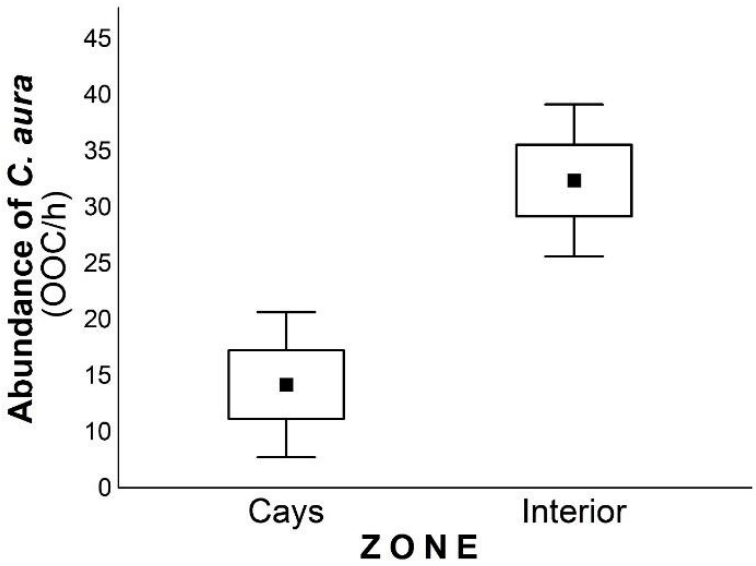
The relative abundances and frequency were also different between regions. In the cays zone, abundance values were lower, ranging from seven to 19 occurrences (Fig. 2b), while in the interior zone the relative abundance values reached 56 occurrences (Fig. 2c). In addition, the amount of area used by Turkey Vulture within the cays zone and the interior zone was different, with high values of probability of presence and larger areas within the interior zone (Fig. 3).

Fig. 3: Area (km2) of use of Turkey Vultures and probability of presence within the cays zone (gray) and interior zone (black) of the GHNCA.



When comparing the relative abundances of the cays zone and the interior zone of the GHNCA (Fig. 4), by counting points, within the cays system these tend to be lower ($Z=-4.373$, $p<0.001$). Within this area, 95% of the sampling stations had abundances between 7 and 20 OCC/h, but with a coefficient of variation greater than 100%. On the other hand, in the interior zone, 95% of the stations showed abundances between 26 and 39 OCC/h (Fig. 4). The results of relative abundances, frequency of observation and probability of presence between each zone acted as a proxy for the spatial approximation of the home range of Turkey Vulture within the study area.

Fig. 4: Comparison between the relative abundances of Turkey Vultures in the cays and interior zone of the GHNCA, Cuba [(■ Mean, □ ±SE and CL (95%)].



In relation to land uses, the relative abundances of Turkey Vultures (Fig. 5) were greater for mangroves and forests, both within the cays zone and in the interior zone ($H(5, N=111)=14.991$, $p=0.01$). The lowest values of abundance were related to areas with some degree of anthropogenic intervention (Fig. 5). When the land uses were analyzed, regardless of the zones, the relative abundances were greater within farmlands and grasslands, decreasing in the anthropic and salt ponds categories (Fig. 5).

Fig. 5: Relative abundances of Turkey Vultures by type of land uses within the GHNCA, Cuba [(■ Mean, □ ±SE and CL (95%)].

DISCUSSION

The presence and abundance of Turkey Vultures varied both between and within each of the regions considered in the study area, as well as in the different land uses that made up each zone. This suggests a certain selection of habitats or preference of use for their different daily foraging and perching activities.

The salt ponds, in the cays zone, had the highest local temperature values, associated with the physical refractory characteristics of this substrate (Sruthi and Aslam 2015, Huang et al. 2002). Temperature differences between the substrate and the immediate atmosphere generate masses of updrafts which, depending on other atmospheric factors (wind, atmospheric pressure, precipitation), may favor the generation of thermal uplift (MELLONE *et al.*, 2012; NÄGELI *et al.*, 2021). These thermals are used by Turkey Vultures for its movements at different spatial and temporal scales (SMITH, 1980; BILDSTEIN *et al.*, 2007; MELLONE *et al.*, 2012). The average temperature of the cays area was lower compared to the interior area, despite not having been verified, differences in this physical characteristic and its relationship with Turkey Vulture for its flight movements may have contributed to the differences in the abundances between zones. In the cays zone the forest obtained the highest NDVI values, suggesting some integrity and spatial heterogeneity compared to forests in the interior zone. The high values of NDVI together with the fact that it is an area surrounded by sea and with high wind dynamics, could act by mitigating the temperature within the cays zone (MELLONE *et al.*, 2012; SRUTHI and ASLAM, 2015). In the interior zone the highest surface temperature values were associated with farmlands. This type of land use represents large continuous and spatially homogeneous areas; its low NDVI values reflect its low floristic complexity and the high local anthropogenic intervention (SRUTHI and ASLAM, 2015).

For the cays zone, the shortest distances were associated with coast and roads, the smaller spatial extension of this area and the fact that the roads are positioned along this spatial axis may have conditioned this result. However, different investigations show an association of this species with roads, either due to differences in thermal refraction (development of thermal uplift) or by animal collisions, acting as food resources (SMITH, 1980: 849 per 100 km; BILDSTEIN *et al.*, 2007: 146 per 100 km; PALOMINO and CARRASCAL, 2007). In fact, another important factor to take into account is the carrion detection capacity of this species, which is greater in these areas where there is a shorter Flight Initiation Distance (FID: TRYJANOWSKI *et al.*, 2020), even more so if we consider that the Turkey The vulture responds positively to this measure of stress. On the other hand, higher distances were associated with water bodies, since the physiological requirements of Turkey Vultures do not show strong dependence on water or its availability (WALLACE, 2004;

PARTRIDGE and GAGNÉ, 2023). In the interior zone, distances were smaller when associated with roads and water bodies, while the greatest distances were to coasts and urbanized areas. Differences in these distances suggest habitat selection and alternation of the presence of this species in the different land uses according to their daily activities and the availability of resources of each land use (MORELLI *et al.*, 2015; TRYJANOWSKI and MORELLI, 2018; NÄGELI *et al.*, 2021; PARTRIDGE and GAGNÉ, 2023). In the interior zone, the water bodies are close to farmlands and grasslands, land uses that Turkey Vultures also selects for its foraging activities and where it presented the highest abundance values (WALLACE, 2004; PALOMINO and CARRASCAL, 2007; PARTRIDGE and GAGNÉ, 2023). In a positive feedback, Turkey Vulture benefits from anthropogenic actions and vice versa; it is a species reported in rubbish dumps of different latitudes from tropical regions to the Malvinas Islands and their scavenging eating habits prevent the proliferation of infectious foci (RAMSDEN, 1916; AUGÉ, 2017; BALLEJO *et al.*, 2021; PARTRIDGE and GAGNÉ, 2023). Their high densities associated with these anthropogenic disturbances suggest that they act as communal foraging sites, however, they also represent a threat to this and other species: plastic wastes have been reported in the stomach contents of Turkey Vultures (TRYJANOWSKI *et al.*, 2020; BALLEJO *et al.*, 2021).

Our results coincided with Ferrer-Sánchez and Rodríguez-Estrella (2015): Turkey Vultures showed wide distribution and high relative abundance in comparison with other bird species reported in the GHNCA ecosystem. However, there were variations in the relative abundances and distribution of the species within the different land uses. Following Wallace (2004), the species is not negatively affected by human disturbance; anthropogenic actions of different intensity and frequency may even increase the presence of the species in these places. In fact, Turkey Vulture has home ranges of up to 1,227.5 km2 using different land uses across the landscape (COLEMAN and FRASER, 1989; KIRK and MOSSMAN, 2020). According to Kirk and Mossman (2020), human actions modulate the populations of *C. aura*. However, although it is not the objective of this research and it has not been evaluated, the demographic patterns of Turkey Vultures do not appear to be modulated by predators, competitors or anthropogenic action. In fact, different investigations state that, for vultures, the availability of forage sites and the structure of vegetation condition and limit the establishment of communal sites for perches, nests and overnight stays (DODGE *et al.*, 2014; BALLEJO *et al.*, 2018; KIRK and MOSSMAN, 2020).

Farmlands and grasslands of the GHNCA showed greater structural stability and greater associated abundances, suggesting that the resource that Turkey Vulture exploits in these land uses is distributed homogeneously and abundantly. Our results coincide with different investigations where the highest abundance values of Turkey Vulture were associated with grasslands and farmlands (PALOMINO and CARRASCAL, 2007; TINAJERO *et al.*, 2017; PARTRIDGE and GAGNÉ, 2023). Both grasslands and farmlands have wide open areas with abundant food resources, avoiding competitive exclusion and favoring the establishment of communal nesting, perching and overnight areas (AUGÉ, 2017; TINAJERO *et al.*, 2017; BALLEJO *et al.*, 2018; PARTRIDGE and GAGNÉ, 2023). The moderate anthropogenic actions that structure these land uses allow them to maintain diverse populations of both migratory and resident birds, but especially generalists (SMITH, 1980; RODRÍGUEZ-ESTRELLA, 2007; TRYJANOWSKI *et al.*, 2020). Turkey Vulture is a generalist species that not only tolerates cultivated areas, but also positively selects these habitats, showing high relative abundances associated with them (MORELLI *et al.*, 2015; TINAJERO *et al.*, 2017; PARTRIDGE and GAGNÉ, 2023). On the other hand, in these land uses, the amount of refractory energy generated favors the generation of thermal uplift (MELLONE *et al.*, 2012; SRUTHI and ASLAM, 2015, NÄGELI *et al.*, 2021). In this work, the highest values of temperature and relative abundance of Turkey Vulture were associated with farmlands, coinciding with the results of different investigations (MANDEL *et al.*, 2008; TINAJERO *et al.*, 2017; PARTRIDGE and GAGNÉ, 2023). Although the highest temperature values were obtained in the cays zone, the relative abundance values were not high. However, high relative abundances associated with ecosystems of open desert or semi-desert areas have already been described (RODRÍGUEZ-ESTRELLA, 2007; MONTAÑO-CENTELLAS *et al.*, 2023).

Forests and mangroves have high complexity and spatial heterogeneity, increasing the quantity and quality of available ecological niches and the richness of associated species (RICARDO *et al.*, 2009; FERRER-SÁNCHEZ and RODRÍGUEZ-ESTRELLA, 2015; 2021; MONTAÑO-CENTELLAS, *et al.*, 2023). For Turkey Vulture, this richness of species in the forests translates into a diversity of food items. The high abundance of occurrences that we have reported in plain flight over the forests can be argued by the turbulence generated in the tree canopy (MELLONE *et al.*, 2012; NÄGELI *et al.*, 2021). Compared to other land uses, relative forest abundance values were intermediate; however, different investigations show a strong association of Turkey Vultures with these land uses (BILDSTEIN *et al.*, 2007; RODRÍGUEZ-ESTRELLA, 2007; PARTRIDGE and GAGNÉ, 2023).

The proportions and dimensions of the urbanized areas of the Sabana-Camagüey landscape are low compared to other land uses in the region, unlike many urbanized areas. These anthropogenic mosaics have high levels of afforestation, which is a factor that conditions the presence of birds, acting as niches for protection, nesting, feeding and perching (MANDEL *et al.*, 2008; SACCO *et al.*, 2015; PARTRIDGE and GAGNÉ, 2023). Different investigations highlight that Turkey Vulture is favored within urban areas, even more so if in these areas there is a high proportion of trees that can provide communal perch and overnight sites (SACCO *et al.*, 2015), or rubbish dumps for feeding (BALLEJO *et al.*, 2021). However, the relative abundance we obtained for this land use was low, despite the high level of associated tree planting. One possible explanation could be that the spatial availability of niches does not compensate for the decrease in food resources caused by anthropogenic factors (PALOMINO and CARRASCAL, 2007; SACCO *et al.*, 2015; TRYJANOWSKI *et al.*, 2020). Anthropogenic actions, without proper waste management, affect the quality and quantity of organic food resources available to vultures, acting as good predictors of their demographic patterns, abundances and spatial distribution patterns.

CONCLUSIONS

This work allows to expand the knowledge about the current state of the population of Turkey Vulture in the GHNCA and to better understand the associations of the relative abundances of this species to the different land uses identified in this RAMSAR site. The differences in the distribution patterns and abundance of the species were different both between each of the areas evaluated and within them. In both areas Turkey Vultures showed association with certain land uses, which could suggest some habitat selection, in accordance with the foraging daily activities, overnight and perch. Future regional anthropogenic actions could affect the patterns of distribution and abundance of Turkey Vultures.

ACKNOWLEDGMENTS

We thank the independent and anonymous reviewers who contributed to the improvement of this manuscript. We are also thankful to the Cuban government for promoting the professional and academic development of young people from different countries.

REFERENCES

AUGÉ, Amélie A. Anthropogenic debris in the diet of turkey vultures (Cathartes aura) in a remote and low-populated South Atlantic island. **Polar Biology**, v. 40, n. 4, p. 799-805, 2017. https://doi.org/10.1007/s00300-016-2004-0

BALLEJO, Fernando *et al.* Trophic niche overlap among scavengers in Patagonia supports the condor-vulture competition hypothesis. **Bird Conservation International**, v. 28, n. 3, p. 390-402, 2018. https://doi.org/10.1017/S0959270917000211

BALLEJO, Fernando *et al.* Plastic ingestion and dispersion by vultures may produce plastic islands in natural areas. **Science of the Total Environment**, v. 755, p. 142421, 2021. https://doi.org/10.1016/j.scitotenv.2020.142421

COBB, Wm Battle. The Soils of Cuba. By Hugh H. Bennett, soil scientist, Bureau of Soils, US Department of Agriculture, and Robert V. Allison, formerly chemist and soil biologist, Tropical Plant Research Foundation. 101 illustrations. Pp. xxiv+ 410. 4 maps, including large soil map of Cuba in folio with key to the principal soils of Cuba. Price, $6.25. Published by the Tropical Plant Research Foundation, Washington, DC. **Science**, v. 68, n. 1754, p. 136-137, 1928. https://doi.org/10.1126/science.68.1754.136.b

BILDSTEIN, Keith L. *et al.* Seasonal abundances and distributions of Black Vultures (Coragyps atratus) and Turkey Vultures (Cathartes aura) in Costa Rica and Panama: Evidence for reciprocal migration in the Neotropics. **Neotropical Raptors (KL Bildstein, DR Barber, and A. Zimmerman, Editors). Hawk Mountain Sanctuary, Orwigsburg, PA, USA**, p. 47-60, 2007. https://www.hawkmountain.org/download/?id=4948

BROWN MANRIQUE, Oscar *et al.* Caracterización de precipitaciones diarias en el municipio de Ciego de Ávila, Cuba. **Ingeniería Hidráulica y Ambiental**, v. 38, n. 2, p. 44-58, 2017. https://riha.cujae.edu.cu/index.php/riha/article/view/388

COLEMAN, John S.; FRASER, James D. Habitat use and home ranges of black and turkey vultures. **The Journal of Wildlife Management**, p. 782-792, 1989. https://doi.org/10.2307/3809213

DODGE, Somayeh *et al.* Environmental drivers of variability in the movement ecology of turkey vultures (Cathartes aura) in North and South America. **Philosophical Transactions of the Royal Society B: Biological Sciences**, v. 369, n. 1643, p. 20130195, 2014. https://doi.org/10.1098/rstb.2013.0195

FERRER-SÁNCHEZ, Yarelys; RODRÍGUEZ-ESTRELLA, Ricardo. Man-made environments relationships with island raptors: endemics do not cope with habitat changes, the case of the island of Cuba. **Biodiversity and Conservation**, v. 24, p. 407-425, 2015. https://doi.org/10.1007/s10531-014-0819-y

FERRER-SÁNCHEZ, Yarelys; RODRÍGUEZ-ESTRELLA, Ricardo. Identifying best conservation areas for an endangered and endemic raptor in Cuba through abundance spatial modeling: A niche-centroid distances approach. **Global Ecology and Conservation**, v. 31, p. e01877, 2021. https://doi.org/10.1016/j.gecco.2021.e01877

HORTAL, Joaquín *et al.* Seven shortfalls that beset large-scale knowledge of biodiversity. **Annual Review of Ecology, Evolution, and Systematics**, v. 46, p. 523-549, 2015. https://doi.org/10.1146/annurev-ecolsys-112414-054400

HUANG, Chengquan *et al.* Derivation of a tasselled cap transformation based on Landsat 7 at-satellite reflectance. **International journal of remote sensing**, v. 23, n. 8, p. 1741-1748, 2002. https://doi.org/10.1080/01431160110106113

JOHNSTON, Peter; MITCHELL, Kieren J. Contrasting patterns of sensory adaptation in living and extinct flightless birds. **Diversity**, v. 13, n. 11, p. 538, 2021. https://doi.org/10.3390/d13110538

KIRK, D. A.; MOSSMAN, M. J. Turkey vulture (Cathartes aura), version 1.0. In: **Birds of the World**. Ithaca, NY, USA: Cornell Lab of Ornithology, 2020. https://doi.org/10.2173/bow.turvul.01

MANDEL, J. T. *et al.* Movement ecology of migration in turkey vultures. **Proceedings of the National Academy of Sciences**, v. 105, n. 49, p. 19102-19107, 2008. https://doi.org/10.1073/pnas.0801789105

MCKNIGHT, P. E; NAJAB, J. Mann-Whitney U Test. *In*: WEINER, I.B; CRAIGHEAD, W. E. **The corsini encyclopedia of psychology**. Volume 3. 4 ed. Eds.; John Wiley & Sons, Inc., New York, 2010. p. 960

MENÉNDEZ-PÉREZ, Homero *et al.* Caracterización hidroquímica del Gran Humedal del Norte, Ciego de Ávila, Cuba/Hydrochemical characterization of the Northern Great Wetland, Ciego de Ávila, Cuba. **Minería y Geología**, v. 27, n. 2, p. 15-41/42-66, 2011.

MONTAÑO-CENTELLAS, Flavia *et al.* Global patterns and drivers of raptor phylogenetic and functional diversity. **Global Ecology and Biogeography**, v. 32, n. 2, p. 281-294, 2023. https://doi.org/10.1111/geb.13619

MORELLI, Federico *et al.* The vulture in the sky and the hominin on the land: three million years of human–vulture interaction. **Anthrozoös**, v. 28, n. 3, p. 449-468, 2015. https://doi.org/10.1080/08927936.2015.1052279

NÄGELI, Melanie *et al.* Weather and food availability additively affect reproductive output in an expanding raptor population. **Oecologia**, p. 1-14, 2021. https://doi.org/10.1007/s00442-021-05076-6

MELLONE, Ugo *et al.* Interspecific comparison of the performance of soaring migrants in relation to morphology, meteorological conditions and migration strategies. **PLoS One**, v. 7, n. 7, p. e39833, 2012. https://doi.org/10.1371/journal.pone.0039833

PALOMINO, David; CARRASCAL, Luis M. Threshold distances to nearby cities and roads influence the bird community of a mosaic landscape. **Biological conservation**, v. 140, n. 1-2, p. 100-109, 2007. https://doi.org/10.1016/j.biocon.2007.07.029

PARTRIDGE, Hannah C.; GAGNÉ, Sara A. Urban vultures preferentially roost at sites surrounded by landscapes with fewer edges between forest and urban development and near water. **Urban Ecosystems**, p. 1-10, 2023. https://doi.org/10.1007/s11252-023-01332-0

QGIS Development Team (2020) **QGIS Geographic Information System**. Open Source Geospatial Foundation Project (http://qgis.osgeo.org)

RAMSDEN, C. T. El Aura Tiñosa Cathartes aura. (Linn.). Resultado de experimentos hechos para probar sí propaga enfermedades por la vía digestiva. **Memorias de la Sociedad Cubana de Historia Natural "Felipe Poey",** 2:174-178, 1916.

RICARDO, N. *et al.* Tipos y características de las formaciones vegetales de Cuba. **Acta Botánica Cubana**, v. 203, p. 1-42, 2009.

RODRÍGUEZ-ESTRELLA, Ricardo. Land use changes affect distributional patterns of desert birds in the Baja California peninsula, Mexico. **Diversity and distributions**, v. 13, n. 6, p. 877-889, 2007. https://doi.org/10.1111/j.1472-4642.2007.00387.x

SACCO, Anne G. *et al.* Perda de diversidade taxonômica e funcional de aves em área urbana no sul do Brasil. **Iheringia. Série Zoologia**, v. 105, p. 276-287, 2015. https://doi.org/10.1590/1678-476620151053276287

SMITH, Neal G. Hawk and vulture migrations in the Neotropics. **Migrant birds in the Neotropics: ecology, behavior, distribution, and conservation (A. Keast and ES Morton, Eds.). Smithsonian Institution Press, Washington, DC**, p. 51-65, 1980.

SOBRINO, José A.; JIMÉNEZ-MUÑOZ, Juan C.; PAOLINI, Leonardo. Land surface temperature retrieval from LANDSAT TM 5. **Remote Sensing of environment**, v. 90, n. 4, p. 434-440, 2004. https://doi.org/10.1016/j.rse.2004.02.003

SRUTHI, Swathandran; ASLAM, M. A. Mohammed. Agricultural drought analysis using the NDVI and land surface temperature data; a case study of Raichur district. **Aquatic Procedia**, v. 4, p. 1258-1264, 2015. https://doi.org/10.1016/j.aqpro.2015.02.164

STATTERSFIELD, A. J.; CAPPER, D. R. **Threatened birds of the world**: the official source for birds on the IUCN Red List. Lynx editions, Barcelona, 2000. (https://iucnredlist.org)

TINAJERO, Romeo; BARRAGÁN, Felipe; CHAPA-VARGAS, Leonardo. Raptor functional diversity in scrubland-agricultural landscapes of northern-central-Mexican dryland environments. **Tropical Conservation Science**, v. 10, p. 1940082917712426, 2017. https://doi.org/10.1177/1940082917712426

TRYJANOWSKI, Piotr *et al.* The emergence of tolerance of human disturbance in Neotropical birds. **Journal of Tropical Ecology**, v. 36, n. 1, p. 1-5, 2020. https://doi.org/10.1017/S0266467419000282

TRYJANOWSKI, Piotr; MORELLI, Federico. Effects of habitat and time of day on flock size of Turkey Vultures in Cuba (Cathartes aura). **ZooKeys**, n. 726, p. 79-87, 2018. https://doi.org/10.3897/zookeys.726.14581

WALLACE, M. **New World vultures**. Pp. 275-285 in: Hutchins M, Thoney D, McDade M. Volume. 8, 2 Edition. Detroit, 2014.

WOTZKOW, CARLOS; WILEY, JAMES W. Turkey vulture surveys in Cuba. **Journal of Raptor Research**, v. 22, n. 1, p. 3-7, 1988. http://elibrary.unm.edu/sora/jrr/v022n01/p00003-p00007.pdf

Recebido para publicação em março de 2023
Aceito para publicação em maio de 2023