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Man-made environments relationships with island raptors: endemics do not cope with habitat changes, the case of the island of Cuba

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Abstract Several studies conducted in neotropical islands have found that the intensity of human activity has altered the original structure and richness of bird communities, strongly affecting endemic species. Despite these effects, studies are limited, and lacking for raptors, in contrast to temperate and continental regions. During breeding and non-breeding seasons of 2012, roadside surveys and point counts were conducted in natural and humantransformed areas of the island of Cuba to determine whether or not raptors from an island show a pattern of ecological response to human activity similar to those observed in continental studies. Raptors showed strong variation in relation to habitat transformations, with lower richness, abundance, and density in the more extensively transformed areas. A total of 11 species was recorded, mostly in natural areas. Similar numbers of species were observed in coastal vegetation and cattle pasture habitat types within each zone. Nine species were detected in agriculture, while ten were found in forest habitat. A gradient of species-habitat was identified: Specialists/endemics tend to occur in natural areas, "intermediate species" in moderately modified areas and generalists in heavily modified areas. Generalists had higher abundances in anthropogenic areas, whereas specialists were found only in natural areas. Under insular conditions, land use changes can pose major threats for endemic and specialist raptors, seriously compromising their conservation.

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Y. Ferrer-Sánchez Empresa Nacional para la Protección de la Flora y la Fauna, Habana, Cuba Endemic raptors do not cope well with habitat changes on the island, thus a rapid process of species impoverishment might be expected. Establishing a conservation program in Cuba is urgently needed.

Keywords Land use changes \cdot Raptors abundance \cdot Gradient \cdot Endemics \cdot Cuban blackhawk \cdot Gundlach's hawk

Introduction

Raptors are key species in food webs since they have an important influence on the structure and dynamics of natural ecosystems, for they affect the structural patterns and community composition of their prey and can recycle dead animals (Newton 1979). Raptors are also relevant for conservation programs as they are considered good indicators of ecosystem health because of their sensitivity to environmental disturbance (Donázar et al. 2002; Sergio et al. 2008). Forty-six percent of all tropical raptors (59 species) are threatened by habitat loss and fragmentation (Bildstein et al. 1998). Reductions of vegetal cover of forests (e.g. forest loss) lead to a decrease in the density of raptors (e.g. Carrete et al. 2009; Pavez et al. 2010), particularly in tropical species and forest specialists, thereby affecting the ecosystem's composition and functioning (Thiollay 1999). However, other studies have shown beneficial relationships with human activities as long as they do not exceed a threshold (e.g. Vannini 1989; Anderson 2001; Campion 2004).

Most differences in the response of raptors to land use changes have been found between temperate and tropical regions. For instance, Rodríguez-Estrella et al. (1998) found the highest densities of raptors in arid habitats with small gaps containing crop fields; Filloy and Bellocq (2007) claimed that most raptor species seem to be tolerant to agriculture and grazing lands. In contrast, raptors from tropical and subtropical rainforests seem to be a sensitive group, with low tolerance to habitat changes. Woodland raptor species have highest densities in natural areas, and many species have declined due to habitat degradation and ecosystem impoverishment (e.g. woodcutting, agricultural intensification, overgrazing, desertification) (Jullien and Thiollay 1996; Thiollay 2006). The different species responses might be a consequence of both species from temperate and desert environments being more capable of using modified habitats, and a greater specialization towards natural habitats by tropical and subtropical raptors. The lack of identifiable patterns in the raptors' response to habitat changes has led to a controversy about the benefit/effect on species (Rodríguez-Estrella 2007; Carrete et al. 2009), probably because the influence of the Nearctic or Neotropical origin of raptors is not fully understood (Rodríguez-Estrella et al. 1998).

Most studies on the effects of human activity on raptor populations have been made in continental ecosystems. Remarkably, ecological information on raptors on Neotropical islands is scarce and limited. It is known that fewer species, but proportionately more endemics, occur on islands than on continents (Cox and Ricklefs 1977). It is also known that human activity has significantly altered the structure and richness of bird communities (Wiley 1985; Feeley and Terborgh 2008), in particular affecting endemic and specialist species negatively (Thiollay 1998). Despite the potential consequences of human activities on tropical species and endemics, there is a lack of studies directly focused on the analysis

of the effects of land use on urban-rural gradients on the distribution and abundance of birds in general, or raptors in particular, in neotropical islands.

On the island of Cuba, 21 species of diurnal raptors are known (Rodríguez-Santana 2009), three of which are threatened and endemic to the island. The Cuban black-hawk (Buteogallus gundlachii) and the Gundlach's hawk (Accipiter gundlachi) are listed as Endangered and the Cuban kite (Chondrohierax wilsonii) is listed as Critically Endangered by the IUCN (Rodríguez-Santana and Viña 2012b; BirdLife International 2013). Several species migrate onto the island during the winter (Rodríguez-Santana 2010). According to the literature, there are both generalists and specialist raptors in Cuba, although studies on their ecology are nonexistent or scarce. This island has lost a significant amount of natural habitat due to changes in land use and fragmentation since the Hispanic colonization in 1492, reducing forest coverage to only 14 % of the territory (González and Fontenla 2007), which might be affecting the species richness and abundance of raptors. In particular, it is hypothesized that habitat loss and transformation in Cuba should affect the endemic raptors more seriously as most of them are ecological specialists (e.g. Cuban black-hawk feeds mainly crabs, Wiley and Garrido 2005; Gundlach's hawk feeds mainly birds, Rodríguez-Santana and Viña 2012a; Cuban kite feeds chiefly on tree snails *Polymita* and slugs in the understory, Raffaele et al. 1998; Kirkconnell 2012). Despite this situation, the effects of habitat changes caused by human activity on the ecology of raptors have seldom been studied. The lack of this information restricts our understanding of the raptors' response to human activity, especially in vulnerable and fragile ecosystems (such as islands, de Groot 1983; González et al. 2008). Given the insularity conditions, it is likely that what is known from continental studies about wildlife responses to human activities is incomplete or can only be partially extrapolated to islands (Cronk 1997). Our aim here is to determine whether raptors from an island show a pattern of ecological response to human activity similar to that of continental raptors. We also examined the responses of single species to habitat degradation to disentangle their individual contributions to community patterns of response. In particular, we wanted to know how endemic raptors cope with habitat changes on an island.

Three predictions were tested. First, based on the hypothesis that Neotropical raptors are sensitive to habitat change, species richness and abundance of resident raptors should be lower in human-transformed than in natural habitats in Cuba. Second, endemic species and ecological specialists will be more negatively affected in man-made environments than resident raptor ecological generalists. Third, migrant raptor species will behave on Cuba in a similar way as on the continent, with regard to being habitat generalists or specialists. To test these predictions we carried out a study to determine the spatio-temporal variations in the species richness, relative abundance and density of wintering and resident populations of raptors both in natural and anthropogenic areas of the island of Cuba. Our goal is to contribute to the conservation of raptor species on islands.

Study area

Field work covered the central region of Cuba, to the north of Ciego de Ávila province, including isolated cays in the coast and inland wetland (4,999 km²) (Fig. 1). This area includes the Gran Humedal del Norte de Ciego de Ávila, a Ramsar site that is part of the La Yana watershed, characterized by a low-lying, partly swampy plain. The landscape also includes a few elevated limestone formations on the northern slopes of the province. The cays along the coast of Cuba harbour diverse plant communities such as mangroves,

xeromorphic coastal shrubs, deciduous forests, microphyllous evergreen forests, halophytic vegetation as well as rocky- and sandy-coast vegetation. The inner parts of the study area are covered by deciduous (mostly mesophytic) forests, evergreen forests, swamp marsh grasslands and second-growth vegetation.

Forests (15.3 % of total study area), mangroves (14.3 %), lagoons (8.8 %), swamp marsh grasslands (5.7 %) and coastal vegetation (0.8 %) were considered as natural areas. Man-made environments were agriculture (35.3 %), cattle pasture (20.5 %) and urban (0.8 %) areas (Fig. 1). Agricultural and cattle pasture areas were considered as man-made environments with moderate modification level, while urban areas were considered as completely modified.

Forests

Forests include deciduous, evergreen and swamp forests. Deciduous forests are widely distributed in the wetland and cays. Plant species can reach 12–15 m in height. Evergreen forests are less extensively distributed. Among the natural habitats analyzed, forests were the most affected and fragmented by sugarcane cultivation, livestock ranching and agriculture.

Mangroves

Mangroves are widely distributed in the cays and the coastline. Tall, mixed or monodominant mangroves (12 m) or dwarf scrub mangroves (3 m) can be found. Tourism development has reduced the mangroves distribution. Roadway construction between the cays and the main island has killed large areas of mangroves. There is also considerable illegal extraction of *Conocarpus erectus* for use as charcoal.

Lagoons

This category included both lagoons and lakes, as well as two water reservoirs. Tourism development in the cays has largely affected the lagoons through the construction of hotels and recreational activities, fishing and changes in water regime as a result of the desiccation and channelling of wetlands.

Swamp marsh

Among the species characteristic of this habitat are *Thypha dominguensis* and *Cladium jamaicense*. The major impacts on this habitat are those associated with changes in the water regime due to piping and draining of wetlands for agricultural purposes. Parts of the marsh have been converted to sugarcane fields and pastures.

Coastal vegetation

Coastal vegetation includes shrubs and rocky- and sandy-coast plant communities. Tourism development has transformed 70 % of the original extent of these vegetation types.



Fig. 1 Locations of point counts and road surveys in Ciego de Ávila, Cuba Island. The spatial arrangement of habitat types is shown

Agricultural areas

These include crops such as rice, sugarcane and fruit trees. Channelling has removed much of the water from the wetland areas. Agricultural areas occur throughout the main island.

Cattle pastures

Pastures for livestock ranching are scattered within the wetland. In most cases, grazing patches of different sizes are inserted within forests, increasing spatial heterogeneity. Traditional cattle and buffalo (*Bubalus bubalis*) ranching is practiced.

Urban areas

The five major urban areas and rural settlements are included in this category as well as hotels and their infrastructure.

Methods

We developed a vegetation and land use map to identify human-modified areas and several classes of natural vegetation (Fig. 1). A supervised classification of two multispectral

Landsat ETM+ images of the study area (date: April 12, 2012; Projection UTM–Datum WGS84, 30 m spatial resolution) was used. Both images were overlapped with a mosaicking algorithm. Thirty-eight training polygons were digitized for each of the eight coverage classes (i.e., mangrove, forest, coastal vegetation, lagoon, swamp marsh, cattle pastures, agriculture, and urban areas) to develop spectral signatures to guide the classification. We then classified the entire image using a maximum likelihood algorithm (Richards 1986). As a basis for supervised classification, greenness, brightness and wetness bands obtained by the Tasseled Cap method were also used. Image processing and analyses were made in ENVI 5.0 (Exelis VIS, Boulder, CO, USA).

Surveys were conducted to record diurnal raptors, including birds of the Accipitridae, Falconidae and Pandionidae families, as well as vultures (family Cathartidae). In order to detect most species and to increase detectability, we used two common-used methods: point counts and roadside surveys (Fuller and Mosher 1981, 1987; Andersen 2007).

Habitat heterogeneity in the study area was taken into account in the study design since it included different distances from the coastline. Points and roadside surveys were located in natural and human-transformed areas. We used stratified random sampling (Fuller and Mosher 1987) to locate fixed points in two environments: natural and human-transformed. Forest, mangrove, lagoons, swamp marsh and coastal vegetation were considered as strata for natural areas. Agricultural areas, cattle pastures and urban areas were considered as strata for human-transformed areas. We randomly allocated the sampling points, based on the proportion of each habitat type within the natural and human-transformed areas. Counts were made at 115 fixed locations, 63 in natural areas and 52 in human-transformed areas during the breeding season. For the non-breeding season, 120 fixed points were established, 65 in natural areas and 55 in anthropogenic areas. Counts were initiated 2 h after sunrise and 2 h before sunset (Fuller and Mosher 1987; Thiollay 1999), between February and July 2012 to encompass the breeding and non-breeding seasons of these birds in Cuba. Point counts were separated by at least 2 km from each other to decrease the probability of double counts of individuals of common species (such as vultures). The observation time was 60 min, with an unlimited radius of observation (Fuller and Mosher 1987); this allowed a better detectability of rare and low density species (Ellis et al. 1990; Thiollay 1999; Rodríguez-Estrella 2007). A preliminary test and the corresponding curve of cumulative species richness showed that 1 h was sufficient to record all the species foraging in the area. Birds were detected both when they soared and when they were perched, flushed or calling. The number of individuals observed, observation distance and habitat type were recorded. Individuals just passing by the area for a short period of time (less than 2 min) were not recorded. Special care was taken to avoid double counting raptors that were first observed, flew behind the observer and then returned into its view-field (Rodríguez-Estrella et al. 1998). Furthermore, the time, behaviour (e.g., hunting, perched, or soaring) and, whenever possible, the gender, age, color morph, molting, and natural marks were also noted to ensure that individuals were not recorded more than once (Zilio et al. 2013). Point counts were made only once in each season, to give maximum independence to the data (Hurlbert 1984).

Raptors were also counted along three road transects (41.5, 31 and 29 km long) separated by 8 and 31 km respectively. Counts were carried out by two experienced observers, for two consecutive days on each month, reversing the start order to further reduce time bias and to avoid directional bias. To minimize differences in detectability between surveys, counts were always made before 13:00 h. Average driving speed was 20–30 km/h. Data recorded were the number of birds observed/species, perpendicular distance from the location to the transect, direction and habitat type in the spot where the bird was observed. To evaluate detectability and to increase the probability of detection of small and uncommon raptor species, we stopped for 5 min every 2 km along roadside surveys to record the birds within a 500 m radius, using rangefinder binoculars (Whitacre and Turley 1990). We only recorded new individuals observed during these stops. We did not record individuals with transit flight behaviour. Adverse weather conditions such as rain, intense heat, or strong wind (>20 km/h) were avoided.

Distance travelled and the surveys' duration were recorded to standardize data (e.g. N/km or N/h). Again, data were analyzed once for each road transect to avoid pseudoreplication (Hurlbert 1984) and double counting. A preliminary analysis of our results showed that all raptors had a high detectability with both sampling methods. Thus, differences in detectability did not significantly affect our final results.

Relative abundance was estimated as the number of individuals observed per hour for point counts, or by kilometre travelled (Johnson and Enderson 1972) for road transects; the latter figures were then expressed as number of birds/100 km. As the transects crossed several habitat types with varying visibility, they were divided into segments and measurements were made in each habitat type to account for differences between natural and human-modified environments (Fuller and Mosher 1987). Although the roadside survey method has limitations, which have been fully described in the literature (Fuller and Mosher 1981), it has been widely used to examine relative abundance, habitat preferences and the effects of habitat degradation on raptors in many large regions and in unknown regions (e.g. Sánchez-Zapata et al. 2003; Carrete et al. 2009). Use of this method allows us to make comparisons of relative abundance with data reported in the literature.

Raptor detectability varies widely between species, time of day, weather conditions, seasons and habitats (Thiollay 1989). Consequently, density was estimated using a conventional distance sampling, which models detection probability as a function of the perpendicular or radial distance from the transect or point, respectively, and assumes all objects at zero distance are detected (Distance 6.0 software; Thomas et al. 2010). This estimation uses a function to compensate for differences in detection probability among species, habitats and routes and distances from points (Buckland et al. 1993).

Using a 1 h count period is advantageous in tropical forests where many birds are cryptic. The likelihood of recording inconspicuous species, specifically at 0 m, increases with count duration (Fuller and Langslow 1984), as the observer has more time to detect and identify species in the surrounding area (Scott and Ramsey 1981; Fuller and Langslow 1984; Verner 1985). However, a disadvantage is the increased probability of birds moving into the area or of being double-counted (Reynolds et al.1980; Fuller and Langslow 1984). Both factors contribute to a positive bias in density estimation as the critical assumption that birds are detected at their initial location, and only once within a single sampling unit, would be violated (Buckland et al. 2001). Length of count period, therefore, becomes a compromise between the need to maximize the probability of recording individual birds with certainty at 0 m, and to avoid overestimating mobile and conspicuous species (Fuller and Langslow 1984; Bibby et al. 1992). However, for multi-species studies like ours, a single optimum count period should not be too long as to seriously overestimate densities of mobile or conspicuous species and not too short as to underestimate densities of inconspicuous species (Fuller and Langslow 1984; Lee and Marsden 2008).

To ensure that estimated densities are not confounded by factors that affect detectability, we took into account the heterogeneity in detectability arising from betweenhabitat variation by stratifying the data from natural habitats and human-modified areas (Thomas et al. 2010). Using Distance 6.0 software, the overall density was estimated as the sum of the stratum-specific estimates. We also fitted half-normal key with cosine adjustments as detection model for the analysis of the bird data. Akaike's information criterion (AIC) was used to identify the best-fitting model for each species; a lower AIC indicating a more robust model (Buckland et al. 2001). The accuracy of distance estimates to bird observations was improved by conducting pre-survey training and previously acquiring experience in distance estimation with rangefinder binoculars.

Species richness was estimated as the total number of species recorded in each habitat sampled. The raptor assemblage data were grouped in a matrix and related to a gradient of human-modification landscapes (natural, medium and completely modified) using a canonical correspondence analysis (CCA) with the XLStat package (http://www.xlstat.com). We wanted to explore whether the assemblage changed in relation to environmental variation, and to identify gradients in the assemblage. CCA is an eigenvector ordination technique for multivariate direct gradient analysis that is also appropriate for occurrence data (terBraak 1986).

For each species, frequency of occurrence was calculated and compared between seasons and areas, using a test of differences between two proportions. To evaluate the similarity in species composition between habitats and seasons, the Whittaker community coefficient (Whittaker 1975) was used. Diversity was evaluated using the Shannon–Wiener index (H'). Relative abundance at points was compared between seasons and between areas using Mann–Whitney's U test.

Results

Total sampling effort in point counts was 235 h and 506.2 km were travelled in road surveys. A total of 11 species in four families (Accipitridae, Falconidae, Pandionidae and Cathartidae) was recorded (Table 1). More species were found in natural environments in both seasons (Fig. 2). However, when the analysis was performed by habitat type within each area, the results showed that there were the same number of species in coastal vegetation (natural area) and cattle pastures (human-transformed area), with 72.7 % (eight species) of the total recorded (Fig. 2; Table 1). More species were recorded in agricultural areas and forests, accounting respectively for 82 and 91 %; only three species were recorded in urbanized areas. However, coastal vegetation and cattle pasture areas had different species composition, with the endemic and specialist Cuban black-hawk present in coastal vegetation and more generalist species in cattle pastures (Table 1). The same pattern was observed in forest and agricultural areas, with 40 % of specialist species (two of them endemics) occurring in forests and more generalist species in agricultural areas (Table 1). Overall, species diversity (H') was higher in natural areas in both point counts (H' = 0.80 vs 0.62, non-breeding season; H' = 0.85 vs 0.34, breeding season) and transect samplings (H' = 1.24 vs 0.68, non-breeding season; H' = 1.16 vs 0.61, breeding season).

Between-habitats similarity in raptor composition during the non-breeding season was generally high and homogeneous, but coastal vegetation and mangroves were more similar to each other (CC = 1.0) in raptor composition as were cattle pastures and agricultural areas (CC = 0.94); urban areas and lagoons were the most dissimilar (CC = 0.25) habitats (Fig. 2). During the breeding season, raptor composition was similar between habitats but agricultural areas were more similar to mangroves (CC = 0.90) and forests (CC = 0.91). Habitats more often used by migratory species were cattle pastures and agricultural areas. The between-seasons Whittaker coefficients for each of these two habitats were low (CC = 0.55 and 0.51), indicating that species are not shared.

Species	Resident status	Total abundance		Pres	ence/a	bsence	by h	abitat			
		Roadside surveys (506.2 km)	Point counts (235)	ц	CV	Μ	Г	SMG	CP	A	D
Family Accipitridae											
Gundlach's hawk (Accipiter gundlachi)	PR, E	2 (0.1)	3 (0.1)	x						Х	
Cuban black-hawk (Buteogallus gundlachii)	PR, E	69 (2.9)	21 (0.8)	Х	Х	X					
Red-tailed hawk (Buteo jamaicensis)	PR	35 (1.5)	57 (2.1)	Х	Х	X		Х	x	X	Х
Snail kite (Rostrhamus sociabilis)	PR	0 (0)	32 (1.2)	Х			X	Х			
Northern harrier (Circus cyaneus) ^a	WR	2 (0.1)	9 (0.3)	Х			X	Х	Х	X	
Family Falconidae											
American kestrel (Falco sparverius)	BR	116 (4.9)	201 (7.4)	Х	Х	X	X	Х	x	X	Х
Merlin (Falco columbarius) ^a	WR	2 (0.1)	1 (0.04)	Х	Х				x	X	
Peregrine falcon (Falco peregrinus) ^a	WR	6 (0.3)	11 (0.4)		Х	X			Х	X	
Crested caracara (Caracara cheriway)	PR	61 (2.6)	17 (0.7)	Х	Х	Х		Х	Х	X	
Family Pandionidae											
Osprey (Pandion haliaetus)	BR	76 (3.2)	86 (3.2)	Х	Х	X	X	Х	Х	X	
Family Cathartidae											
Turkey vulture (Cathartes aura)	PR	2,016 (84.5)	2,262 (83.8)	х	Х	x	X	Х	x	×	X
Species richness: breeding/non-breeding season	7/11	2,385	2,700								
Total	11	5,085		10	×	٢	5	7	8	6	ю

^a Migratory species that were still present in the study area at the beginning of the breeding season



Fig. 2 Species richness of diurnal raptor in natural and human-transformed areas in Ciego de Ávila, Cuba. Whittaker community coefficient denotes the between-seasons similarity in species composition for each habitat

Species data were linearly related to the habitat modification gradient (Pseudo F = 0.25; p = 0.001). The first two CCA axes accounted for the 100 % of the constrained variance, 86.4 and 13.6 % in the species–environment relationship (Fig. 3). Specialist and endemic species such as the snail kite (*Rosthramus sociabilis*), osprey (*Pandion haliaetus*), Cuban black-hawk and Gundlach's hawk were associated with natural areas, while the American kestrel (*Falco sparverius*) and turkey vulture (*Cathartes aura*) were associated with moderately and highly modified areas. Endemic species and specialists only used between 25 and 37 % of the habitats, mainly natural ones, whereas generalists were recorded in all the habitat types (Fig. 4). Intermediate species were observed both in natural and man-made environments; the amount of habitats they used ranged from 50 to 88 % of the total (Fig. 4).

The osprey was observed in several habitats, including human-modified areas (Table 1), but was more frequent in natural habitats. Regardless of habitat type, this species has an aquatic association. Frequency of occurrence varied between seasons for the American kestrel (Spt = 2.3, df = 233, p = 0.02), and the red-tailed hawk (*Buteo jamaicensis*) (Spt = 2.8, df = 233, p = 0.01) (Fig. 5). In both seasons, frequency was higher in natural areas for the Cuban black-hawk (Spt = 2.5, df = 118, p = 0.01, N = 120; Spt = 2.7, df = 113, p = 0.01, N = 115), osprey (Spt = 4.5, df = 118, p = 0.0001; Spt = 3.4, df = 113, p = 0.0001) and crested caracara (*Caracara cheriway*) (Spt = 3.3, df = 118, p = 0.0001; Spt = 2.6, df = 113, p = 0.01). The Cuban black-hawk and the snail kite were never observed in man-made environments, whereas the turkey vulture was always found in these environments (Fig. 5). The frequency of red-tailed hawk in natural areas was eight times higher than in human-transformed areas (Spt = 2.5, df = 113, p = 0.01, I = 0.0001; Spt = 2.6, df = 113, p = 0.01). The Cuban black-hawk and the snail kite were never observed in man-made environments, whereas the turkey vulture was always found in these environments (Fig. 5). The frequency of red-tailed hawk in natural areas was eight times higher than in human-transformed areas (Spt = 2.5, df = 113, p = 0.01, I = 0.



Fig. 3 Effect of the extent of habitat modification on raptors' species composition in the northern region of Ciego de Avila, Cuba, using CCA. Species positioned close to the centroid *Natural* are positively associated only with natural areas, whereas species positioned close to the centroid *Medium modification* use modified areas. Cat.aur: *Cathartes aura*, Fal.spa: *Falco sparverius*, But.jam: *Buteo jamaicensis*, Ros.soc: *Rostrhamus sociabilis*, Pan.hal: *Pandion haliaetus*, But.gun: *Buteogallus gundlachii*, Acc.gun: *Accipiter gundlachi*, Fal.per: *Falco peregrinus*, Car.che: *Caracara cheriway*, Fal.col: *Falco columbarius*, Cir.cya: *Circus cyaneus*



Fig. 4 Number of habitats used by diurnal raptors in Ciego de Ávila, Cuba. Species were grouped into specialists, intermediate and generalists according to the number and variety of habitats used. The Osprey was excluded from the analysis because it has an aquatic-association regardless of habitat type

N = 115), during the non-breeding season. The Gundlach's hawk was only observed in <5 % of point counts, but most of these were in natural areas.

The turkey vulture $(54.1 \pm 15.9 \text{ birds}/100 \text{ km}, 48.2 \pm 8.9 \text{ birds}/h)$ and the American kestrel $(8.8 \pm 6.6 \text{ birds}/100 \text{ km}, 1.8 \pm 0.4 \text{ birds}/h)$ had the highest abundance and density values, compared to other species (Fig. 5). The peregrine falcon (*Falco peregrinus*) and the Gundlach's hawk were the least abundant species. The number of birds/100 km for the Cuban black-hawk, osprey and red-tailed hawk during the non-breeding season were, respectively, 7, 4.8 and 2.7 times higher than during the breeding season. Additional data are given in Online Resource 1.

The abundance of the crested caracara, American kestrel, Northern harrier (*Circus cyaneus*) and turkey vulture was higher in modified areas (p < 0.0001; Fig. 5; Online Resource 2). The osprey was more abundant in natural areas. The red-tailed hawk was three times more abundant in human-transformed areas during the non-breeding than in the breeding season (U = 1,259, p < 0.001), whereas the turkey vulture was 1.6 times more abundant in natural sites during the breeding season (U = 1,439, p = 0.01).

The largest between-area variation in density from road surveys were those observed in the American kestrel (0.8 and 1.3 birds/km2) during the breeding season, and for the turkey vulture in both seasons (Fig. 5), with highest values recorded in human-transformed areas. From count points, crested caracara and red-tailed hawk also had great between-area variation in density (Fig. 5). Additional data are given in Online Resources 2 and 3.

Our results show that the red-tailed hawk, crested caracara, merlin and peregrine falcon were not affected by land use changes. Forty-five percent of the species recorded seem to be negatively affected by human impacts, having a low abundance in or being absent from these areas. This is the case of specialist and endemic Cuban black-hawk and Gundlach's hawk, as well as of the diet specialist osprey and snail kite. A smaller percentage of species (27.3 %), such as the American kestrel, turkey vulture and Northern harrier, benefited from human modifications. Urbanization was the land use change that had the most negative impact on these species.

Discussion

Fourteen species of diurnal raptors have been reported for the northern region of Ciego de Ávila (Sánchez and Rodríguez 2000). In our study, the broad-winged hawk (*Buteo platypterus*), sharp-shinned hawk (*Accipiter striatus*) and swallow-tailed kite (*Elanoides forficatus*) were not observed. The first two species have resident populations living in isolated regions of the country (Rodríguez-Santana 2009) and their abundance increases during fall migration (Rodríguez 2004), but our study did not encompass that season. That these two species were not recorded with the common sampling methods we used may indicate that these species are rare and have very low abundance in the study region. The swallow-tailed kite has two migration routes that traverse Cuba; the largest percentage of kite sightings have been made in the western part of the country but not in the central part of the island (Rodríguez-Santana 2009). This species' distribution range seems to lie outside our study area. Therefore, there was a low probability that these species could be recorded in the time we sampled raptors, despite the high effort invested to detect all the species present in the study area.

Studies on bird communities have reported different results on the relationship between species richness, diversity and habitat changes. Some studies have shown that species richness and diversity generally decrease with intensified agriculture (Carrete et al. 2009;



Fig. 5 Relative abundance (*bars*) and density (*dots*) of diurnal raptors recorded in natural and humantransformed areas of Ciego de Ávila, Cuba, during the non-breeding (\mathbf{a} , \mathbf{c}) and breeding season (\mathbf{b} , \mathbf{d}). *Left:* results from road surveys; *Right*: results from point counts. *Left* and *right* axes are in logarithmic scale. *TV* turkey vulture, *CBH* Cuban black-hawk, *O* osprey, *AK* American kestrel, *CC* crested caracara, *RTH* redtailed hawk, *PF* peregrine falcon, *M* merlin, *NH* northern harrier, *GH* Gundlach's hawk, *SK* snail kite

Butet et al. 2010) and urbanization (Cam et al. 2000; Pavez et al. 2010). Other studies found highest values of species richness, diversity and abundance under moderate habitat changes (Lepczyk et al. 2008; Cardador and Mañosa 2011; Piana and Marsden 2012). Other studies have found no effects of human activities on species richness, suggesting that this parameter is misinterpreted as an indicator of impacts on biodiversity (Brown et al. 2001; Rodríguez-Estrella 2007). Contrary to what was predicted in our island study, species richness was higher in landscapes with moderate levels of human activity, probably due to a greater diversity of habitats and resources compared to pristine or highly modified landscapes (Connell 1978; Anderson 2001). Species richness can be high in crop fields probably because landscape diversity prevents competitive exclusion (Lepczyk et al. 2008), or this is relaxed by the absence of habitat-specialist species. Habitat-specialist species (e.g. Cuban black-hawk, snail kite, Gundlach's hawk and osprey) appear to be affected by habitat degradation, and mostly occur in natural areas. Agricultural and cattle pasture areas sustain populations of both migratory and resident, but mostly generalist species. Agricultural and urban areas are "new habitats" created by human activity in relatively homogeneous dense vegetation (Rodríguez-Estrella 2007). These new habitats seem attractive to some species depending on the extent of transformation. Studies have shown these new habitats offer food, nesting structures and protection against predators (Tella et al. 1996). For species with greater ecological tolerance, habitat openness and changes in land use might be beneficial or, at least, will not affect them. For instance, raptors in desert areas of Baja California Sur have benefited from moderate habitat changes for foraging (Rodríguez-Estrella et al. 1998), with their density increasing around crops and villages, opportunistically exploiting resources such as carrion and garbage (e.g. turkey

vulture and crested caracara, Rodríguez-Estrella 2007). In the Sacramento Valley, California, raptors have benefited from landscape heterogeneity in crops, but have avoided developed and rural areas (Smallwood et al. 1996). In Cuba there is an impoverishment of species richness in urbanized areas, with only the most abundant and generalist species being present there. There exists a gradient of species in relation to environmental variation, from specialists/endemics (Cuban black-hawk, snail kite, Gundlach's hawk and osprey) in natural areas, "intermediate species" (e.g. red-tailed hawk, crested caracara, Merlin) in crops and cattle pastures, and generalists (turkey vulture and American kestrel) in completely modified areas on the island. This pattern has been found in continental areas as well (Julliard et al. 2006). The spatial constraints of endemic, specialist species and their low presence and abundance in modified environments, in addition to the increased abundance of generalist species in the communities, are part of the overall process of biotic homogenization (McKinney and Lockwood 1999), and of the indirect effects that changes in the species abundance and composition of the assemblage have on particular species (Feeley and Terborgh 2008). This may be worse in conditions of insularity, where endemic and specialist species have evolved closely and have developed highly specialized habitat requirements, where there is limited or low habitat availability, in addition to the fragility of island ecosystems. Under insular conditions, land use changes might pose major threats for habitat-specialist raptors, far greater than those observed on the continent. Thus, endemic raptors do not cope well with habitat changes on the island of Cuba.

Between-season variations were exhibited by increases in the number of migrant individuals that use Cuban ecosystems as wintering sites. Therefore, the similarity in raptor composition decreases in those habitats most often used by migratory species. In the case of American kestrel, which benefits from habitat modification as it hunts in open areas, the high abundance and density observed in human-transformed areas during the non-breeding season were probably due to the presence of migrant individuals. Migrants typically displace residents from preferred feeding areas (Bildstein 2004). Thus, residents use mainly natural areas while migratory individuals use modified areas. Permanent residents could probably use a higher diversity of habitats for foraging during the non-breeding season. In the breeding season, kestrels mainly use their preferred habitats. Other examples of species benefited by land use changes in Cuba are the turkey vulture and the Northern harrier, for which agricultural development supplies new habitats. Beneficial effects of habitat fragmentation and moderate land use changes for these species have also been reported from other tropical areas, such as the Atlantic forest in southern Brazil and the Paranaense forest in Argentina (Loures-Ribeiro and dos Anjos 2006; Zurita and Bellocq 2007). A similar pattern was found in desert environments (Rodríguez-Estrella et al. 1998; Tinajero and Rodríguez-Estrella 2012).

The observation of snail kite only in natural areas contrasts with the positive response of this species in agricultural landscapes in Pampas Argentina (Filloy and Bellocq 2007) and the expansion of its distribution range in the Pacific coast of México (Hernández et al. 2013). The distribution range of this species is correlated to that of *Pomacea* snails (Estela and Naranjo 2005). Within the study region in Cuba, this snail occurs in the flooded marsh, shallow lakes and artificial ponds. In our study, the density of crested caracara was not positively related to the percentage of livestock grazing and agricultural areas, as had been previously reported for arid, temperate and tropical ecosystems (Rodríguez-Estrella 2007; Filloy and Bellocq 2007). In Florida, crested caracara is benefited by cattle ranching lands, which are thus important for its conservation (Morrison and Humphrey 2001). Unlike those results, in Cuba the crested caracara had a higher frequency and density in natural areas. This is similar to the trends observed in other Neotropical regions such as Argentina

(Carrete et al. 2009). The effect that human activity has on crested caracara productivity under insularity conditions in the Neotropics should be studied in more depth to better understand the different responses insular populations have, compared to their continental counterparts.

The species' tolerance to open habitats and agricultural areas is a key factor to understand the biological traits of species that allow them to persist in degraded environments and then identify those that could face extinction. Specialist species are strongly affected and would quickly disappear in those environments as a consequence of their lower ecological tolerance. Generalist species may exploit those environments. However, habitat changes can affect the persistence over time even of generalist species: when suitable habitat is drastically reduced and their ecological threshold is exceeded, their populations may decrease dramatically (Campion 2004; Huggett 2005; Butet et al. 2010; Pavez et al. 2010). In our study, several generalist species, such as crested caracara, northern harrier and peregrine falcon, were absent from urbanized areas. Only a few species (e.g. turkey vulture, American kestrel) are able to persist in these environments.

About 73 % of the raptor species recorded in our study was affected, either positively or negatively, by land use changes; 37 % showed a high dependence on natural environments and a low ability to use human-modified areas (e.g. endemics). The high proportion of species affected in an insular environment highlight the impact of human expansion on natural habitats, threatening the long-term persistence of raptor species. These factors more strongly affect resident species, mainly endemics and resource specialists. This pattern repeatedly appears in other studies in tropical forests where most species are specialists (Thiollay 1996; Jullien and Thiollay 1996; Zurita and Bellocq 2007). By contrast, in the rainforests of Guatemala moderate habitat changes have increased the diversity and abundance of raptor species (Vannini 1989), similar to what has been observed in temperate ecosystems. Probably raptor communities from temperate regions include more generalist species, whereas tropical species are mostly forest specialists with narrow niches and little tolerance to habitat changes.

Conservation implications

Our results have important implications for conservation in Cuba and even, we propose, for other Neotropical islands. The negative effects of habitat alteration on raptors may worsen if the agricultural area is expanded into the wetlands or by conversion to monoculture forestry. Currently, several endemic and generalist species use adjacent natural areas as nesting sites and opportunistically exploit nearby patches of croplands and pastures for prey hunting. If agricultural areas expand, suitable habitat for nesting birds would be reduced and a decrease in the populations of both generalist and specialist species would be expected. Similarly, tourism development in the cays will also affect raptors. Habitat changes are a main concern if coverage of coastal vegetation, mangroves and forests decreases as the threatened endemic species, Cuban black-hawk and Gundlach's hawk, breed there.

The particular situation of the northern region of Ciego de Avila can also apply to the whole island, as the same threats for raptors occur throughout. Gundlach's hawk has lost 80 % of its suitable habitat in the entire island and the size of the remaining forest patches in most territories does not seem to be sufficient to ensure the presence of isolated populations (Rodríguez-Santana 2009). A similar situation has been reported for Cuban blackhawk, which has lost 75 % of its suitable habitat in Cuba (Rodríguez-Santana 2009), which

is mostly concentrated in the central region, where tourism development is increasing. Gundlach's hawk and Cuban black-hawk have been considered as widely distributed species in Cuba, mainly present in forests and coastal zones throughout the island (Garrido and Kirkconnell 2000). We are concerned about these two endemic raptors because they have several isolated populations restricted to particular habitat types and have small population sizes. They have a fragmented distribution that makes populations vulnerable to extinction (Stratford and Stouffer 1999; Rodríguez-Santana and Viña 2012a, b).

Cuba's National System of Protected Areas does not effectively protect these two endemic raptor species: over half of the suitable habitat within the distribution range of each species currently lacks any legal protection. Regions like the Zapata peninsula and the mountain massifs in eastern Cuba encompass and protect only ca. 7 % of the Gundlach's hawk's occupancy area. The Sabana-Camagüey archipelago and the Zapata swamps may protect almost 26 % of the Cuban black-hawks occupancy area, including suitable and unsuitable habitats (Rodríguez-Santana 2009). If habitat changes in Cuba continue increasingly affecting the remaining suitable habitat of the endangered Gundlach's hawk and Cuban black-hawk, we can expect these species to become even rarer and threatened by extinction in the medium-term. National Protected areas are insufficient to stop and reverse the population decline of these endemic endangered species. Alternatively, if habitat loss and fragmentation of the nesting habitats of these endemic raptors is controlled, we expect these species to become more common and reverse their populations' decline at least in the remaining suitable habitats. Endemic hawk species are associated with natural habitats without human activity. Thus, if endemic species are to be preserved, conservation strategies should be directed towards maintaining natural areas as their populations' recovery depends on the existence of natural areas with little disturbance. There is an urgent need for studies designed to determine the impacts of tourism on the productivity and nesting areas of the Cuban black-hawk, for example. Immediate priority should be given to establishing a conservation program particularly focused on these two species. Such a program should involve the government, protected area managers and researchers in Cuba and should include the protection of nesting areas, expanding the protection of natural protected areas containing suitable habitat for both species in forest and coastal areas, and restoring suitable nesting habitats.

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