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Notes on the breeding biology of common resident birds in an urbanized area of Hidalgo, Mexico.

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Abstract
We present data on the breeding biology and nest site characteristics of the six most frequent nesters in a small ecological reserve immersed in the city of Pachuca, Hidalgo, Mexico: *Columbina inca* (Inca Dove), *Pyrocephalus rubinus* (Vermilion Flycatcher), *Campylorhynchus brunneicapillus* (Cactus Wren), *Toxostoma curvirostre* (Curve-billed Thrasher), *Pipilo fuscus* (Canyon Towhee), and *Carpodacus mexicanus* (House Finch). We followed 65 active nests, mainly of *C. mexicanus* and *C. brunneicapillus*; density of nests reached up to 15 nests ha^{-1} in some areas of the park. The main causes of reproductive failure in the failed nests (74%) were heavy storms and human disturbance. Nests were found on seven plant substrates, mainly on *Cylindropuntia imbricata* and *Cupressus* spp. Data on nest site characteristics, including the plants used for nesting, their average height and dbh, average height of the nest, clutch size, extent of the breeding season, and particular causes of nest failure is presented for each species. At the end we suggest some general management recommendations that will aid in the conservation of breeding birds in parks of central Mexico.
Key words: nest site characteristics, breeding phenology, reproductive failure, Pachuca, urbanization.

Notas sobre la biología reproductiva de aves residentes comunes en una zona urbanizada de Hidalgo, México.
Resumen
Presentamos información sobre la biología reproductiva y las características del sitio de anidación para seis especies de aves comunes en una pequeña reserva ecológica inmersa en la ciudad de Pachuca, Hidalgo, México: *Columbina inca* (tórtola cola larga), *Pyrocephalus rubinus* (mosquero cardenal), *Campylorhynchus brunneicapillus* (matraca del desierto), *Toxostoma curvirostre* (cuitlacoche pico curvo), *Pipilo fuscus* (toquí pardo) y *Carpodacus mexicanus* (pinzón mexicano). Seguimos 65 nidos activos, principalmente de *C. mexicanus* y *C. brunneicapillus*. La densidad de nidos alcanzó 15 nidos por hectárea en algunas áreas del parque. Las principales causas de fracaso reproductivo en los nidos fracasados (74%) fueron las fuertes lluvias y el disturbio humano. Los nidos se encontraron en siete sustratos diferentes, principalmente en *Cylindropuntia imbricata* y *Cupressus* spp. Presentamos, para cada especie, datos sobre las características del sitio de anidación, incluyendo las plantas utilizadas para anidar, el promedio de su altura y diámetro a la altura del pecho, altura promedio del nido, tamaño de nidada, extensión de la temporada de anidación y causas particulares de fracaso reproductivo. Al final, sugerimos algunas recomendaciones generales de manejo que pueden ayudar a la conservación de aves que anidan en parques del centro de México.
Palabras clave: características del sitio de anidación, fenología reproductiva, fracaso reproductivo, Pachuca, urbanización.

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Introduction

Collecting information on breeding biology and performance is an important part of many population ecology studies on birds, and it is often essential in identifying effective conservation measures (Green 2004). For many bird species that breed in Mexico, there is still very little published information on breeding phenology, nest site characteristics, nest microhabitat, and causes of reproductive failure, even for species that are widespread, conspicuous, or associated with human habitats. This knowledge is relevant for conservation and management purposes, especially in areas with high urbanization rates, like many places in Mexico, where urban growth is not well planned or regulated, resulting in the reduction, isolation, and degradation of habitat.

Urbanization is increasing especially in developing nations, and there is an urgent need to thoroughly review and comprehend its effects on wildlife in order to understand both the ecological implications of increasing urbanization, and how to mitigate its threat to biodiversity (McKinney 2002, Chamberlain *et al.* 2009). Several studies have analyzed the effects of urbanization on bird diversity and community composition (*e.g.*, Beissinger and Osborne 1982; Blair 1996; Marzluff

2001; Chace and Walsh 2006, Donnelly and Marzluff 2006), but only a few have explored the urban impacts on bird breeding biology (reviewed by Chamberlain *et al.* 2009). The knowledge of nesting requirements, breeding seasons, and other aspects of the reproductive biology of resident birds in urbanized landscapes would help land managers and administrators to develop compatible management strategies with avifauna conservation.

Here we present some data on the breeding biology and nest site characteristics of the six most frequently encountered nesters in a small ecological reserve immersed in the city of Pachuca, Hidalgo, Mexico: *Columbina inca* (Inca Dove), *Pyrocephalus rubinus* (Vermilion Flycatcher), *Campylorhynchus brunneicapillus* (Cactus Wren), *Toxostoma curvirostre* (Curve-billed Thrasher), *Pipilo fuscus* (Canyon Towhee), and *Carpodacus mexicanus* (House Finch). Most studies on the breeding biology of these species have been done in North America, especially in Arizona, USA (reviewed by Hill 1993, Tweit 1996, Johnson and Haight 1996, Proudfoot *et al*. 2000, Wolf and Jones 2000, and Mueller 2004), and many authors report the need to study populations of these species in other regions. For example, Proudfoot *et al*. (2000) reported the need to study *C. brunneicapillus* populations in Mexico; Wolf and Jones (2000) concluded that most aspects of the life history of *P. rubinus* remain unknown, habitat requirements for the species need to be more clearly delineated, and the causes and rates of mortality, annual and lifetime reproductive success, and population regulation are areas needing further study; Mueller (2004) also reported the need for more studies on *C. inca*, stating that even though it is expanding its range in North America and thus generates little conservation concern, this species has not been the subject of enough research. We also identified the causes of reproductive failure for nesting birds in this area and propose some general management recommendations.

Methods

The study was conducted in a small ecological reserve immersed in the city of Pachuca (Figure 1), an area with a high rate of population growth (mean annual growth rate for the period 2000-2005 up to 9.0%, INEGI 2008) and high population density (about 1,411 people per km^2, INEGI 2008). The reserve, called "Parque Ecológico Cubitos", has an extension of 90 ha, and it is located between 20º06´33"-20º07´39"N and 98º44´60"-98º45´00"W, with an elevation of 2,300 m. The natural vegetation is represented by open scrub forest or arid tropical scrub (Rzedowski 1994). The dominant species are agaves (*Agave lechuguilla*, *A. salmiana*), yucca (*Yucca filifera*), several cacti species (*Cylindropuntia imbricata*, *Opuntia streptacantha*, *O. spinulifera, O. robusta, Stenocactus sp., Coryphantha sp.*), and the non-native pepper tree or pirul (*Schinus molle*), among others (COEDE 2004). A smaller portion of the park is covered by introduced vegetation, including several species of pines (*Pinus cembroides*, *P. torreyana*, *P. pinceana*), cypress (*Cupressus guadalupensis, C. macrocarpa),* and other trees like pirul and privet (*Ligustrum japonicum*). The park is divided in two main areas: a small area designed for recreational purposes, that includes the area covered by introduced vegetation, and an area where human access is restricted.

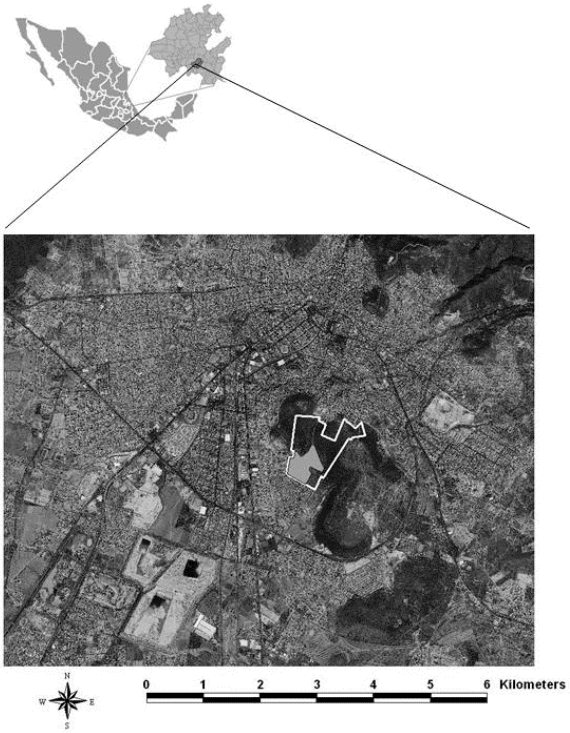

Figure 1. Location of Parque Ecológico Cubitos (PEC) in the state of Hidalgo, Mexico. The shaded polygon inside the park represents the recreational area.

The avifauna includes 76 species, 21 considered permanent residents (Zuria *et al.* 2009). Some of the mammals present in the park are potential nest predators: *Bassariscus astutus* (ringtail), *Spermophillus variegatus* (rock squirrel), *Urocyon cinereoargenteus* (gray fox), and domestic dogs and cats (Tirado-Aviles 2009).

We surveyed different areas of the park for nests between June 2005 and December 2006. We followed the methods described by Ralph *et al*. (1993) for locating and monitoring nests. Nests were located mainly during nest construction by searching and following birds with nesting material. Direct searches were also conducted in trees and shrubs where adults were frequently observed.

We recorded the location of each nest using a GPS, and we also recorded the following: bird species, state of the nest (active, inactive, in construction, completed, adults incubating, etc.), nest content (number of eggs, chicks or fledglings), nest substrate (*i.e.*, species of plant containing the nest), plant height (cm), plant dbh (diameter at breast height in cm; however, for cacti we used the diameter of the main stem at 5 cm above the ground), and nest height (cm). We used a one-way analysis of variance (ANOVA) or a Kruskal-Wallis test (non-parametric alternative) to compare plant and nest height between species. The Tukey test (or the Dunn's method for the non-parametric test) was used for a posteriori comparisons of means when the previous analyses indicated significant effects (Sokal and Rohlf 1995). Analyses were performed using SigmaStat ver. 3.5. All nests were checked every three days and we recorded any change in status and the date it occurred. From all our observations we constructed a breeding calendar for each of the six species considered.

For each nest we also obtained hatching success or the percentage of eggs that hatched from the nests (Gore and Kinnison 1991), and nest success or the percentage of nests that fledged at least one young. We also identified the causes or reproductive failure based on nest and egg remains, and classified them in the following categories: "nest destroyed by rain" which included nests partly destroyed on the plant or on the floor that were found after a heavy storm; "nest destroyed by a predator" consisted of nests found in the original place, but without its contents, with hair, tracks or excrement in the vicinity; "human disturbance" included nests that completely disappeared, with footprints in the vicinity, or when we saw evidence that the tree had been pruned; and "unknown" (Green 2004).

Results

We were able to follow 65 active nests, most of them being of *Carpodacus mexicanus* and *Campylorhynchus brunneicapillus* (Table 1). Density of nests reached up to 15 nests ha^{-1} in some areas of the park, especially in the area covered by introduced trees, where *Carpodacus mexicanus*, *Columbina inca*, and *Pipilo fuscus* were the most abundant nesters; *C. brunneicapillus* nests were abundant in the area covered by natural vegetation. The hatching and nest success were variable among species (Table 1), *Toxostoma curvirostre* was the most successful nester since two out of the three nests fledged at least one young, while *C. brunneicapillus* had the lowest nest success (Table 1). In general, 74% of the nests failed; most nests that failed (54%) were destroyed by heavy storms, in particular, the most affected species were *C. brunneicapillus*, *C. mexicanus*, *C. inca*, and *Pyrocephalus rubinus*. Six percent of the failed nests were destroyed by humans, who stole chicks and damaged nests during maintenance operations (*e.g.*, pruning); *Pipilo fuscus* and *Carpodacus mexicanus* were most affected by human activities. We could not determine the causes of nest failure in 35% of the failed nests, and we only registered two events of nest predation.

Table 1. Common species that nest in Parque Ecológico Cubitos, Hidalgo, Mexico (June 2005 -December 2006), with average hatching and nest success. Clutch size interval and the one reported in the literature for each species are shown; hatching success is the percentage of eggs that hatched from each nest; nest success represents the percentage of nests that fledged at least one young. SD = standard deviation.

Family	Species (Common name)	# Nests	Mean clutch size ± SD (range)	Hatching success (%)	Nest success (%)	Clutch size reported in literature
Columbidae	*Columbina inca* (Inca Dove)	2	2.0 ± 0.0 (2)	50.0	50.0	2 (Mueller 2004)
Tyrannidae	*Pyrocephalus rubinus* (Vermilion Flycatcher)	2	2.5 ± 0.7 (2-3)	50.0	50.0	2-5 (Wolf and Jones 2000)
Troglodytidae	*Campylorhynchus brunneicapillus* (Cactus Wren)	21	3.0 ± 0.6 (2-4)	14.3	19.0	1-5 (Proudfoot *et al*. 2000)
Mimidae	*Toxostoma curvirostre* (Curve-billed Thrasher)	3	2.3 ± 0.6 (2-3)	66.7	66.7	2-5 (Tweit 1996)
Emberizidae	*Pipilo fuscus* (Canyon Towhee)	2	2.0±0.0 (2)	100.0	50.0	2-4 (Johnson and Haight 1996.)
Fringillidae	*Carpodacus mexicanus* (House Finch)	35	3.0 ± 0.9 (1-5)	31.4	22.8	1-6 (Hill 1993)

Nests were found on seven plant substrates, mainly on *Cylindropuntia imbricata* and *Cupressus* spp. (Figure 2). Most frequently used substrate varied among species; for example, *Campylorhynchus brunneicapillus* nested mainly on *Cylindropuntia imbricata*, while *Carpodacus mexicanus* used *Cupressus macrocarpa* (Table 2). In general, we found significant differences in plant heights used by the species ($H = 36.17$, d.f. = 5, $P < 0.001$). *Carpodacus mexicanus* nested in significantly taller plants than *Campylorhynchus bruneicapillus* (Table 2), while all other comparisons between species were not significant. We also found significant differences in nest heights ($F = 6.32$, d.f.= 5, 67, $P < 0.001$), and again the only significant difference was between *Carpodacus mexicanus* and *Campylorhynchus bruneicapillus* (Table 2).

The extent of the breeding season for each species showed that *Carpodacus mexicanus* presented the longer breeding season, since we observed individuals involved in breeding activities from January to November. *Pyrocephalus rubinus* presented the shorter breeding period. May, June and July can be considered the most important months of the breeding season in the park because all species were nesting (Table 3).

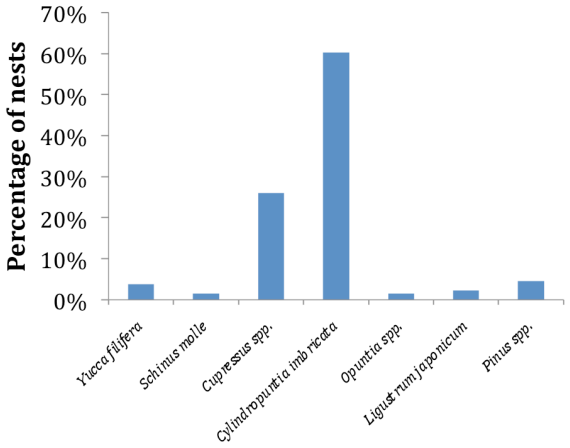

Figure 2. Percentage of active nests found on different plant substrates in Parque Ecológico Cubitos, Hidalgo, Mexico.

Table 2. Mean characteristics (± standard error) of nest site location, and plant species used as substrate, in six common bird species that nest in Parque Ecológico Cubitos, Hidalgo, Mexico (June 2005 - December 2006). Range is included in parenthesis below the mean ± standard error values.

Species	# Nests	Plant height (m)	Plant dbh (cm)	Nest height (m)	Plant species used as substrate
Columbina inca (Inca Dove)	2	3.5 ± 0.7 (1.9 – 5.1)	12.0 ± 0.9 (9.3 – 13.0)	2.1 ± 0.3 (1.6 – 3.0)	*Cupressus guadalupensis* *Schinus molle*
Pyrocephalus rubinus (Vermilion Flycatcher)	2	3.5 ± 1.4 (2.1 – 4.8)	15.7 ± 6.7 (9.0 – 22.3)	2.5 ± 0.7 (1.8 – 3.2)	*Pinus cembroides*
Campylorhynchus brunneicapillus (Cactus Wren)	21	1.7 ± 0.1 (1.0 – 2.6)	11.9 ± 0.7 (6.0 – 16.0)	1.5 ± 0.1 (0.7 – 2.4)	*Cylindropuntia imbricata* *Yucca filifera* *Ligustrum japonicum* *Opuntia* spp.
Toxostoma curvirostre (Curve-billed Thrasher)	3	1.9 ± 0.1 (1.8 – 2.0)	15.7 ± 0.3 (15.0 – 16.0)	1.6 ± 0.02 (1.5 – 1.6)	*Cylindropuntia imbricata*
Pipilo fuscus (Canyon Towhee)	2	2.8 ± 0.4 (2.5 – 3.2)	16.6 ± 4.5 (12.1 – 21.0)	2.0 ± 0.1 (1.8 – 2.1)	*Ligustrum japonicum* *Schinus molle*
Carpodacus mexicanus (House Finch)	35	4.5 ± 0.3 (1.1 –7.6)	14.5 ± 0.7 (3.2 – 21.1)	2.6 ± 0.2 (0.7 – 5.6)	*Cupressus macrocarpa* *C. guadalupensis* *Yucca filifera* *Pinus cembroides* *P. torreyana* *P. pinceana* *Cylindropuntia imbricata*

Table 3. Breeding calendar for six common bird species in Parque Ecológico Cubitos, Hidalgo, Mexico. Rectangles in gray indicate our observations of breeding activities in the park. The extent of the breeding season reported in the literature (Hill 1993, Johnson and Haight 1996, Tweit 1996, Proudfoot *et al*. 2000, Wolf and Jones 2000, Mueller 2004) for each species is indicated with X.

Species	Jan			Feb			March			April			May			June			July			Aug			Sep			Oct			Nov			Dic		
Columbina inca	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pyrocephalus rubinus							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																
Campylorhynchus brunneicapillus							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X											
Toxostoma curvirostre					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X													
Pipilo fuscus					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							
Carpodacus mexicanus							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X													

Discussion

The six species considered in this study reproduce in the park, and we observed fledglings for all of them. Although these species can be common in urbanized landscapes, it is still necessary to study some aspects of their breeding biology, especially south of the USA. Knowledge of the breeding seasons, nesting requirements and causes of failure is fundamental in order to design adequate management strategies, especially for Latin American countries, where these factors are rarely considered in urban development or when designing green areas in cities.

Overall, the most frequently used nesting substrates in the park were cane cholla (*Cylindropuntia imbricata*) and cypress trees (*Cupressus* spp.). These two species represent the two types of nesting substrates present in our study site: native plants common in the natural vegetation and introduced vegetation. The presence of both types of substrates probably favors a more diverse bird breeding community, and particular plant species can be used in order to attract some birds. For example, most nests of *Campylorhynchus brunneicapillus* were found on cane cholla, knowledge that can be used for management purposes. It has been reported that some birds prefer to nest under the greater protective cover of exotic plants than native plants, but more studies are needed in order to understand if introduced vegetation could be acting as a population sink for some species, because predators may also be using these areas for foraging (Chace and Walsh 2006). Nesting substrates and nest heights for the six species studied coincide with previous reports for North America (reviewed by Hill 1993, Johnson and Haight 1996, Tweit 1996, Proudfoot *et al*. 2000, Wolf and Jones 2000, Mueller 2004).

In general, clutch sizes for most species were in the low end of the clutch size range reported in the literature (Table 1). Lower clutch sizes have been observed in urban landscapes, especially for species living at high densities, which may experiment a greater competition for food in the breeding season that could lead to lower clutch sizes (Chamberlain *et al.* 2009). More studies are needed to understand how natural and artificial food may influence demographic differences, especially in urbanized landscapes.

Few studies have explored the urban impacts on reproductive success (Chace and Walsh 2006). Identifying the causes of nest failure in urbanized landscapes is also important in order to understand bird demography and productivity, which in turn may allow us to adopt adequate management strategies. In our study, heavy precipitations, accompanied by high winds, observed during the rainy season (May to October), were the main cause of reproductive failure. In 2005 and 2006 the mean annual precipitation was below average in this region of Mexico (CNA 2008); however, during 2005 hurricane activity was above average (Rosengaus and Hernández-Unzón 2005) with seven hurricanes affecting Mexico, and with several storms registered in the state of Hidalgo (CNA 2008). Heavy precipitation has been reported before as the most important cause of reproductive failure (*e.g.*, DeSante and Geupel 1987). However, some species are able to renest two or three times after a nest has been destroyed. It is known that *Campylorhynchus brunneicapillus* (Proudfoot *et al*. 2000), *Toxostoma curvirostre* (Tweit 1996), *Pipilo fuscus* (Johnson and Haight 1996) and *Carpodacus mexicanus* (Hill 1993) can renest several times in a single nesting season. So it is possible that many of the nests we observed later in the season were second or third nesting attempts. Human disturbance was the second cause of reproductive failure, especially in areas of the park where human access was permitted for recreational purposes. People stole chicks and destroyed nests during maintenance operations (*e.g.*, pruning). We registered only a few nest predation events. However, it is possible that predation could have been higher since we were not able to identify the cause of failure for many nests. A large number of nest predators like domestic cats and dogs, as well as gray foxes, have been observed in the park. In Mexico, abandoned cats and dogs roam freely in urbanized landscapes and sometimes form feral populations that are not managed adequately. It is known that domestic predators are responsible for the high

predation rates observed in many urban settings (Hoover *et al*. 1995, Jokimâki and Huhta 2000, Haskell *et al.* 2001, Chace and Walsh 2006, Forrest and Clair 2006).

The extent of the breeding season was variable for the species studied, but all were breeding from May to July. We observed shorter breeding periods than those reported before (reviewed by Johnson and Haight 1996, Wolf and Jones 2000, Mueller 2004) for *Columbina inca*, *Pyrocephalus rubinus*, and *Pipilo fuscus* (Table 3). However, this observation can be a result of the low number of nests found for these species. Increasing sample size in future studies may allow us to get a better picture of the extent of the breeding season. On the other hand, we observed longer breeding seasons for *Toxostoma curvirostre* and *Carpodacus mexicanus* than those reported before (Hill 1993, Tweit 1996, Table 3). It has been shown that some bird species may lay earlier in urbanized landscapes perhaps due to the availability of anthropogenic food and water which leads to better pre-laying feeding conditions (reviewed by Chamberlain *et al.* 2009). Laying may also be advanced by the higher temperatures observed in urban areas which reduce pre-breeding energy requirements (Chamberlain *et al.* 2009). Food and temperature may also be responsible for the breeding activities observed later in the year for these two species.

Birds nesting in urbanized landscapes must tolerate many annoying factors in order to reproduce successfully, for example human disturbance (*e.g.*, noise, human presence, management practices, etc.), pollution, predators (Haskell *et al*. 2001), and the presence of different or exotic nesting substrates (Reichard *et al*. 2001). However, green spaces in urban areas are important for many birds because they represent the only places where birds can find adequate nesting substrates and feeding opportunities. It is still possible to improve breeding conditions for birds in urban areas if adequate management practices are adopted. Based on our observations, we suggest some general management recommendations that will aid in the conservation of breeding birds in parks of central Mexico: (1) maintenance operations should be limited or restricted while birds are nesting, therefore it is necessary to know the breeding calendar of the species that inhabit the green area. In particular for Parque Ecológico Cubitos, maintenance operations should be minimized from May to July. (2) Populations of domestic cats and dogs, and other invasive predators that roam vegetated areas should be controlled. (3) A program to educate park administrators, managers and the general public on the importance of birds in urban areas should be developed and implemented.

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