

## Nest-spacing, not human presence, influences the breeding of Chimango Caracaras (*Milvago chimango*) in a peri-urban reserve

Claudina Solaro<sup>A,B</sup> and José Hernán Sarasola<sup>A</sup>

<sup>A</sup>Centro para el Estudio y Conservación de las Aves Rapaces en Argentina (CECARA) – CONICET, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, Avenida Uruguay 151, Santa Rosa (6300), La Pampa, Argentina.

<sup>B</sup>Corresponding author. Email: [csolaro@conicet.gov.ar](mailto:csolaro@conicet.gov.ar)

**Abstract.** Natural environments have been greatly transformed by human populations and activities and the responses of species to these changes vary. In human-dominated environments, birds may adopt behaviours that enable them to adjust to these novel habitats. We analysed the reproductive ecology of a common and human-tolerant bird of prey, the Chimango Caracara (*Milvago chimango*), in a peri-urban zone in central Argentina in response to different levels of human presence. A total of 34 nests were monitored. Nests were in dense colonies with a random distribution of nests within the colony. The reproductive output of Chimango Caracaras was not affected by levels of human presence at either the local scale (colony site) or within colonies (distance to neighbouring nests). However, the lower reproductive success in our study compared with that observed in natural habitats suggests that this species may be negatively affected by anthropogenic factors at a very local scale (i.e. a breeding colony in a peri-urban area) despite its behavioural plasticity and apparent tolerance to human presence.

**Additional keywords:** colonialism, human perturbation, nest spatial arrangement, raptor bird, reproductive success, urban environments.

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### Introduction

Increasing urbanisation results in the loss, fragmentation and degradation of natural habitats and can result in increased edge effects (Murcia 1995). Increased urbanisation may also result in remnant native habitat, for example in reserves or parks, becoming isolated 'islands' surrounded by urban areas (Miller and Hobbs 2000); in such sites, the species richness, abundance and use of habitat by birds might be affected by human recreational activities (Cardoni *et al.* 2008).

The mechanisms that regulate the response of avian populations to the environmental changes associated with urbanisation vary, as do the responses of individual bird species to such anthropogenic change (Sol *et al.* 2005; Carrete and Tella 2011). Recent studies have shown that species with relatively large brains and high frequency of foraging innovations tend to be more successful invaders and able to exploit a wider variety of ecological contexts than those species that interact only with native biota (Sol and Lefebvre 2000), suggesting that the ability to coexist with highly modified environments is an important selective advantage for some animal populations. Although some species colonise or adjust well to human-modified environments (Cardilini *et al.* 2013; Cavalli *et al.* 2013), others seem to be more sensitive to human pressures (Darby and Seddon 1990; Carrete and Tella 2011). Among other factors, the magnitude and

incidence of anthropogenic effects may be related to the social behaviour of species (Kark *et al.* 2007). Colonial breeding birds, for example, may be more susceptible to human disturbance than solitary nesters (Blumstein 2006).

During the reproductive period some raptorial birds are able to take advantage of the resources that anthropogenic environments provide (Stout *et al.* 1998, 2006, 2007; Rottenborn 2000; Hobbs *et al.* 2006). The Chimango Caracara (Falconidae: *Milvago chimango*) may be one such species. This medium-size raptor (250–300 g) is the most common bird of prey in southern South America (Ferguson-Lees and Christie 2001). It is considered tolerant of human presence and with the behavioural plasticity that enables it to occupy different environments (Biondi *et al.* 2008). The Chimango Caracara is a generalist predator that hunts opportunistically depending on local food availability (Biondi *et al.* 2005; Baladrón *et al.* 2009). In captivity, it has also been shown to solve novel feeding problems (Biondi *et al.* 2008, 2010), a skill that may increase its ability to adapt to human environments, such as agroecosystems and urban areas. Other studies, however, have found that increasing urbanisation has negative effects on the abundance of Chimango Caracaras (Bellocq *et al.* 2008). Despite the varying responses of this species to human pressure, one of the key determinants of fitness – reproductive success – has not been evaluated in the

anthropogenic environments where the Chimango Caracara is commonly observed. In addition, although a few studies on the breeding biology of Chimango Caracaras have described the varied environments in which the species breeds (Fraga and Salvador 1986; Morrison and Phillips 2000), little is known about the pattern of spatial distribution of Caracara nests. Knowledge of the extent of coloniality in the Chimango Caracara is important because the spatial arrangement of nests can strongly influence behaviour, such as food competition, protection from predators and reproductive success, and thus, ultimately, evolutionary fitness (Sachs *et al.* 2007).

We examined the effects of different levels of human presence on breeding parameters of the Chimango Caracara, including reproductive success, reproductive productivity, size of clutches and broods, and fledgling body condition in an anthropogenic habitat. We also evaluated the spatial arrangement of Chimango Caracara nests in this anthropogenic habitat and the effect of this on breeding parameters.

## Materials and methods

Our study area was a 17-ha patch of natural Caldén (*Prosopis caldenia*) forest within a suburban area of ~30 km<sup>2</sup> between the cities of Santa Rosa and Toay in La Pampa Province, central Argentina (36°39'21"S, 64°20'44"W). The 17-ha patch of Caldén forest is a remnant within the urban matrix and is currently a private reserve, 'Club de caza mayor y menor Mapú Vey Puudú', within a residential area. The study area comprised two distinct zones: a tourist zone (13 ha), where recreational activities are allowed, and an adjacent fenced zone (4 ha, enclosed by a wire fence 2 m tall) containing native and exotic ungulates, such as Llamas (*Lama lama*) and Red Deer (*Cervus elaphus*), and in which tourists are not allowed. There is significant human recreational activity in the tourist area of the reserve, especially during spring–summer, with ~80 people per day on weekdays and up to 250 on weekend days (A. Holzman, pers. comm.) and much lower levels of human presence in the fenced enclosure than in the rest of the reserve.

From October 2007 to January 2008 (austral spring and summer), we searched for nests in the forest reserve. Nests were considered to be active from the first visit when the nest contained fresh grass, eggs or an adult was observed sitting (incubating). Once found, the location of each nest was recorded using a global positioning system (GPS) and classified as either within the tourist or non-tourist area of the reserve.

Once located, nests were visited every 2–5 days. For each nest, we calculated: clutch-size (number of eggs per nest), brood-size (number of chicks per nest), the number of young fledged per nest (productivity), and breeding success for individual nests (defined as fledging at least one young from the nesting attempt) and for the populations (the number of successful breeding pairs divided by the total number of pairs attempting to breed in the area).

We also calculated fledgling body condition based on the repeated visits to nests. At each visit, chicks were weighed (to the nearest 0.1 g, using a digital scale) and measured (length of eighth primary (p8) to the nearest 1 mm). The residuals of the geometric mean regression between body-weight and the length of p8 were used as a body condition index (BCI) at fledging (Green 2001; Sarasola *et al.* 2004). We evaluated the effects of

NND (included in models as a continuous independent variable) and the level of human occurrence (treated as a two-level factor, tourist v. non-tourist area) on BCI. Because the values of body condition of fledglings from the same nest are not independent, we used linear mixed effects (LME) modelling and included nest as a random effect.

We analysed the spatial distribution of breeding in two ways. First, we calculated the nearest-neighbour distance (NND) and analysed the spatial distribution pattern of nests with nearest-neighbour analysis (NNA) (Clark and Evans 1954). The NNA index analyses potential regularity in nest-spacing by comparing the actual pattern of nest-settlement with a theoretical random pattern. The NNA algorithm uses values between 0.00 and 2.15 and attempts to measure the spatial arrangement of nests based on three categories: clustered, random and spaced-regular distributions. Secondly, we also classified the spatial distribution of nests as: territorial or non-colonial (distances between nests of 0.2–30 km); loosely colonial (70–200 m between nests); and densely colonial (<70 m between nests) (after Newton 1979).

We also evaluated the effects of intraspecific (i.e. NND) and anthropogenic covariates on nest predation and on four reproductive parameters (reproductive success, clutch- and brood-size, and productivity) by building generalized linear models (GLM) using the software R (R Development Core Team 2009). Predation and reproductive success were treated as binomial variables (each nest was classified as depredated or not depredated and successful or not successful) and a logit-link function; models of productivity, and clutch- and brood-size, were built using a Poisson error distribution and a log-link function. NND was included in these models as a continuous independent variable. We chose NND as a covariate because spacing of nests may have effects on the reproductive performance of individuals associated with exposure to predators or interactions with conspecifics for territorial or colonial species (Solaro and Sarasola 2012). A second independent variable was the level of human occurrence, which was treated as a two-level factor (tourist v. non-tourist area in the forest reserve).

We built five models to test the significance of covariates on the response variables related to reproductive output. We included all possible combinations of main effects and their interactions in the models. We used the Akaike Information Criterion (AIC; Burnham and Anderson 2002), the second-order AIC (AICc), the  $\Delta$ AICc, and AICc weight ( $w$ ) to select the best models. Within a response variable, each model was considered as a hypothesis explaining the performance of this variable. The best hypothesis was weighed against the others using AICc weight, which gives an estimation of the likelihood of the hypothesis given the data.

## Results

We found 34 breeding pairs of Chimango Caracaras during the 2007–08 reproductive season. Eleven nests were in the tourist zone and 23 nests in the non-tourist zone. Overall reproductive success for the 34 nests was 32.3%. Reproductive success, productivity, and rate of predation were not significantly affected by NND or by the level of human occurrence (Table 1). The best models explaining variation in clutch-size and brood-size were those retaining only NND as an explanatory variable: nests

**Table 1. Best models explaining the reproductive success, productivity, predation risk, clutch-size and brood-size of Chimango Caracara in a suburban environment in La Pampa, Argentina**  
NND, nearest neighbour distance; HO, human occurrence

Response variable	Model	AICc	$\Delta$ AICc	w
Reproductive success	NND	40.54	0	0.39
	Null model	40.78	0.25	0.34
Productivity	NND + HO	60.94	0	0.43
	NND	61.41	0.47	0.33
Predation	NND	39.61	0	0.37
	Null model	39.65	0.03	0.36
Clutch-size	NND	103.51	0	0.48
	Null model	104.81	1.30	0.25
Brood-size	NND	104.74	0	0.54

farthest from their nearest neighbour had the largest clutches and broods (Table 1).

We obtained between one and 11 repeated and paired measures per individual for body-weight and length of p8 for 31 nestlings. From these, we selected only the last paired measures closest to fledging. The length of p8 and body-weight were strongly correlated after log-transformation ( $R^2 = 0.77$ ) and the regression between these two variables was highly significant ( $F_{1,34} = 52.23$ ,  $P < 0.01$ ). Variability in the body condition of nestlings was not explained by additive or interaction effects of NND and level of human occurrence ( $\Delta$ AICc differences with null model  $> 5$ ).

Mean distance between nests was 29.12 m (s.d. = 26.02, range 2.8–162.6 m,  $n = 34$  nests, with one outlier to 162.5 m), showing a colonial spatial distribution of nests (*sensu* Newton 1979). Analysis of NNA determined a value of 0.99 for spatial distribution of nests, indicating that Chimango Caracara nests were randomly distributed within the colony. We analysed the spatial distribution of breeding in two ways: the NNA analysis (Clark and Evans 1954) and the classification proposed by Newton (1979).

## Discussion

Birds living in urban areas can cope with environmental limitations by exhibiting broader environmental tolerance than their conspecifics in natural habitats (Bonier *et al.* 2007). Behavioural, physiological and ecological flexibility may contribute to the ability of a bird to tolerate a broad array of environmental conditions, including disturbed habitats and human disturbance (Bonier *et al.* 2007).

Although based on a fairly small sample size and, therefore, possibly low statistical power, the breeding ecology of Chimango Caracaras in an urban landscape reveals the tolerance of the species to human presence and showed differences with previously reported observations of the species. For example, the percentage of nesting failures was higher than those values reported for southern Chile (Morrison and Phillips 2000).

Previous studies on the relationship between this raptor species and urban environments have found a negative response of species abundance to increasing urbanisation (Bellocq *et al.* 2008). However, this seems not to prevent Chimango Caracaras from breeding in urban environments, as they are one of the few Neotropical raptors that consistently breed in urban areas. These

contradictory results suggest that the effects of anthropogenic pressures on Chimango Caracaras should be reconsidered. As reported for avian communities in the Pampean region, which appear to show changes in composition, richness and abundance with the size of the urbanised area (Garaffa *et al.* 2009), Chimango Caracaras may be positively influenced at low or intermediate levels of urbanisation but is negatively affected at greater levels of urbanisation.

The spatial arrangement of Chimango Caracara nests indicate the species is densely colonial (*sensu* Newton 1979). The spatial arrangement of nests has not previously been measured for the species and it seems to have important implications for the breeding ecology of Chimango Caracaras. Distance between neighbouring nests appeared first (alone or additively) in the top-ranking models explaining reproductive outputs and also negatively affected the size of clutches and broods. The effects of spacing between neighbouring breeding pairs would also explain the non-clustering distribution of nests inside the colony.

Although Chimango Caracaras are tolerant of human-modified environments (Carrete and Tella 2013), our results indicate that several aspects of their behaviour and ecology in urban landscapes may be determined by anthropogenic pressures that ultimately drive their fitness in these modified habitats.

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