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SHORT COMMUNICATION



## Breeding phenology and nest survival of Cinereous (*Circus cinereus*) and Long-winged (*C. buffoni*) Harriers in the agricultural landscapes of north-east Patagonia, Argentina

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### ABSTRACT

We present novel data on breeding ecology and nest survival of the Cinereous (*Circus cinereus*) and Long-winged (*C. buffoni*) Harriers in modified grasslands of southern Argentina and we evaluate variations in daily nest survival rates (DSR) in relation to temporal and habitat variables. We studied three mixed nesting colonies embedded in agricultural landscapes along a road. We found that DSR decreased linearly with time of breeding and increased with vegetation height above the nest and the distance to the road. This is the first and most complete reproductive study concerning two species of conservation concern, namely the Cinereous and Long-winged Harriers in Patagonia. Our study provides valuable and novel insights into the population dynamics of these little-known species.

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### Introduction

Raptors are top predator species with relatively low population densities, large home ranges and specific ecological requirements for foraging and breeding sites, which makes them especially vulnerable to human disturbances (Carrete *et al.* 2009). Harriers (*Circus* spp.) represent a small cosmopolitan group of raptors of the family Accipitridae (16 species; Del Hoyo and Collar 2014). One of their particularities is that they nest on the ground, which makes them especially sensitive to human alterations of their natural habitats (Thiollay 1994).

Habitat degradation linked to human modification of landscapes is known to negatively affect bird species (Murphy 2003; Haines-Young 2009), including harriers, through alterations of their hunting and nesting habitats (Thiollay 1994). Human-caused landscape modification does not affect all species in the same way, and transformed landscapes still provide suitable habitats for some tolerant harrier populations (Cardador *et al.* 2011; Sternalski *et al.* 2013; but see Millon *et al.* 2002; Amar and Redpath 2005).

In South America there are only two species of medium-sized harriers, the Cinereous Harrier *C. cinereus* and the Long-winged Harrier *C. buffoni* (Del Hoyo and Collar 2014). Little is known about the general


biology of these species and there is no information available on the relationship between habitat characteristics and their breeding biology (Thiollay 1994). Understanding the relationships between reproductive parameters and habitat characteristics may provide insight for predicting the consequences of land-use changes on the ecology and population dynamics of species of conservation concern. This study presents data on the breeding ecology of Cinereous and Long-winged Harriers nesting in modified grasslands of the southern cone of South America. Our aim was to provide novel information on the breeding ecology of both species, with particular emphasis on variations in nest survival in relation to temporal and habitat variables.

### Methods

#### Study area

The study was conducted in three mixed nesting colonies located east and west of General Conesa, eastern Rio Negro province, throughout the southern margin of the 'Negro' river (40°06'21" S, 64°27'27" W; Figure S1 in the online supplementary material). This region is characterised by warm summers (maximum temperature: 41.2°C) and cold winters (minimum temperature: -13.5°C), with most precipitations occurring between November–March. The

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National Meteorological Survey of Argentina from 1980 to 2010 reports mean annual rainfall as 271 mm and mean annual temperature as 15°C. All colonies were situated on the northern margin of Road 251, in the 'Monte de Llanuras y Mesetas' ecoregion (hereafter 'Monte' ecoregion; Brown and Pacheco 2006). The three colonies are characterised by natural pasture (*Stipa* spp., *Poa ligularis* and *Psila spartiroides*), implanted pastures (mainly *Thynopyron elongatum*) and native Cattail (*Typha latifolia*) in flooded areas. Wetlands in this area remain flooded year-round by the constant water leaks of artificial irrigation channels from neighbouring crop areas. The southern part of the colonies is representative of the Monte ecoregion with large areas of natural vegetation altered by extensive and low-density cattle grazing. In contrast, the northern area, which includes the nesting colonies, has been intensively modified with artificial water channels to irrigate the extensive crop zones. Potential nest predators of our study area include Grey Fox (*Lycalopex griseus*), Bay-winged Hawk (*Parabuteo unicinctus*) and Domestic Dogs (*Canis familiaris*). During the middle-late nestling stage, when parents are absent from the nest most of the time, other potential predators are White-eared Opossums (*Didelphis albiventris*), Large Hairy Armadillos (*Chaetophractus villosus*), Lesser Grisons (*Galictis cuja*) and Southern Caracaras (*Caracara plancus*).

### Study species

The Cinereous Harrier is distributed from south-west Colombia and Ecuador through Peru, Bolivia, Paraguay, southern Brazil and Uruguay to southern Argentina and Chile. The Long-winged Harrier ranges from south-west Colombia and north-east Brazil to central Argentina and Chile through south-east Bolivia and Paraguay (Del Hoyo and Collar 2014). Both species inhabit various habitat types in Argentina, such as savannahs, wetlands, pastures, grasslands and crop areas. The Cinereous Harrier is seen more frequently in the arid or semi-arid areas of central and southern Patagonia (Thiollay 1994). Both species show marked similarities in their reproductive biology as they nest in open-ground colonies (occasionally mixed) and they are diurnal solitary hunters (Thiollay 1994).

### Nest monitoring

We collected data during four consecutive breeding seasons (2009–2010, 2010–2011, 2011–2012 and 2012–2013), from late September to early March. In the last breeding season (2012–2013), we monitored only Long-winged Harrier nests. The nests were

found by observing adults' behaviours, especially when they transported nesting material and food. We monitored the nests every 4–6 days until nestlings fledged or the nest failed. From day 25 of nestling age onwards we inspected nests from a distance of 3–5 m to minimise the risk of premature fledging. Egg measurements (width and length) were taken from a subsample of 15 eggs from four nests of the Cinereous Harrier and 10 eggs from three nests of the Long-winged Harrier to the nearest 0.05 mm using Vernier callipers.

We considered a nest successful when at least one nestling fledged from the nest and was not found in the immediate nest surroundings (2–5 m around the nest, since close to the fledging stage it is frequent that the nestlings move within this radius without successfully abandoning the nest). We considered a nest abandoned if the female was absent from the nest as we approached, eggs were cold to the touch and no parental activity was observed near the nest during the visit (i.e. 10–15 min). We considered a nest predated if its contents disappeared between two consecutive visits and there was no parental activity. Nests abandoned before eggs were laid were not considered.

Each nest was assigned a clutch-initiation date (time of breeding), corresponding to the laying of the first egg (day 1 = 1 October). Clutch-initiation dates were determined directly for nests found during construction and egg-laying, or indirectly for nests found during incubation or after hatching (see details in Segura *et al.* 2015).

We selected two temporal factors that might influence nesting success: year and time of breeding. Because nesting site characteristics may influence nest survival, we also recorded: (1) minimum distance to the road (m), (2) distance to the nearest active nest (m), (3) distance to the nearest flooded area (m) and (4) vegetation height above the nest (cm). We measured vegetation height using a pole marked every 5 cm.

### Data analysis

We estimated daily nest survival rates (DSR) using the MARK program (Dinsmore *et al.* 2002). Due to breeding similarities between species (Thiollay 1994; preliminary results of this study), for the purposes of nest survival analysis we gathered information on both species. In the same sense, due to habitat similarities between colonies (mainly in relation to road, flooded areas and vegetation structure – see above), we also gathered information on the three colonies. In both cases we included 'species' and 'colony' as factors in

analysis. We evaluated how seasonal effects impact on nest characteristics and reproductive traits. ‘Year’ was used as categorical variable and ‘time of breeding’ as continuous variable. We examined linear and quadratic effects of time of breeding and then used the best of these models as a base to incorporate models with the physical nesting site characteristics. In the same sense, we also examined linear and quadratic effects of distance to the road, to the nearest active nest, to the nearest flooded area and the vegetation height, since other studies of harriers have shown that certain habitat characteristics may be optimal at intermediate levels (Limiñana *et al.* 2011). We used Akaike’s information criterion adjusted for small sample sizes (AIC<sub>c</sub>) to compare models based on log-likelihood values. We built all models without standardising covariates and with the logit-link function (Dinsmore *et al.* 2002). We ranked and compared models using  $\Delta\text{AIC}_c$  and we considered models with  $\Delta\text{AIC}_c \leq 2$  to be equally parsimonious (Burnham and Anderson 2004). We estimated daily survival rates using parameters of the best-supported models. Values are presented as means  $\pm$  SE.

## Results

We found a total of 62 nests of the Cinereous Harrier and 15 nests of the Long-winged Harrier. Twelve nests of the Cinereous Harrier were found during construction, six during egg-laying, twenty-three during incubation, and twenty-one after hatching, whereas for the Long-winged Harrier, four nests were found during construction, three during egg-laying, four during incubation, and four after hatching. The earliest nest of the Cinereous Harrier was initiated on 17 October and the latest on 10 January, and for the Long-winged Harrier the earliest nest was initiated on 27 October and the latest on 12 January. The earliest and latest fledging dates were 30 December and 1 March for the Cinereous Harrier, and 8 January and 12 February for the Long-winged Harrier, respectively. Clutch initiation for both species showed a unimodal frequency distribution along the season, with a peak in November (Figure S2 in the online supplementary material). The general breeding phenology of both species (clutch size, egg measurements, incubation and nestling periods, egg and nestling survival, hatching success and productivity) and nest site-related variables used in the analysis are detailed in Table S1 (in the online supplementary material).

Models including time of breeding (expressed as a linear trend), distance to the road and vegetation height above the nest had lower AIC<sub>c</sub> values than the

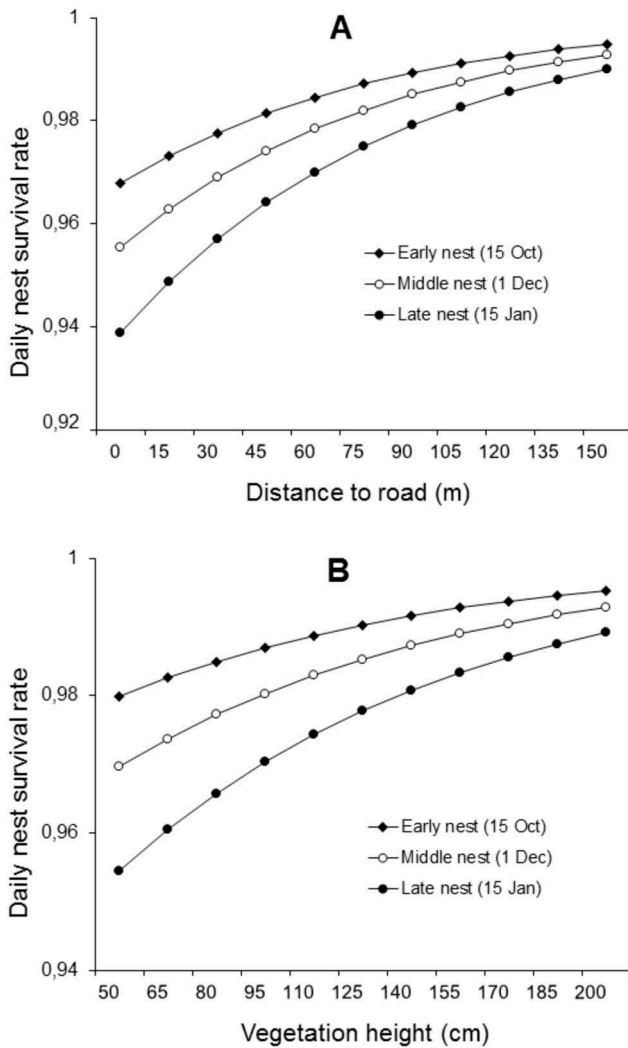
**Table 1.** Support for models predicting daily survival rates for Cinereous and Long-winged Harrier nests in north-eastern Patagonia, Argentina ( $N = 77$  nests during the breeding seasons of 2009–2010, 2010–2011, 2011–2012 and 2012–2013). Deviance = difference between each model and the saturated model in  $-2$  log-likelihood;  $\Delta\text{AIC}_c$  = difference between each model and the top model in Akaike’s information criterion corrected for small samples (AIC<sub>c</sub>); AIC<sub>c</sub> value of the top model = 368.4;  $K$  = number of parameters in the model;  $w_i$  = Akaike weight. S (.) is the general model that assumes a constant DSR among nests and over time.

Model	Deviance	$\Delta\text{AIC}_c$	$K$	$w_i$
S (time of breeding + vegetation + distance to road)	365.9	0.00	4	0.498
S (vegetation)	373.8	1.96	2	0.151
S (distance to road)	382.5	2.03	2	0.132
S (time of breeding)	390.6	2.23	2	0.119
S (.)	392.4	2.26	1	0.091

null model and all of them contributed to building the best model ( $w_i = 0.498$ ; Table 1). AIC<sub>c</sub> values for other models were higher than the AIC<sub>c</sub>’s null model. In all cases, the linear trends of the physical nesting site characteristics fitted better than the quadratic trends. Models including species and colony had lower support than the null model, thus all nests were pooled to get survival estimates. The DSR decreased linearly with time of breeding and increased with vegetation height and the distance to the road (Figure 1). Based on the MARK estimator, an average nest (i.e. initiated on 1 December, located  $\sim 50$  m from the road and with  $\sim 120$  cm of vegetation height above the nest) had an estimated DSR of  $0.988 \pm 0.007$  (range = 0.967–0.996), which represents a mean cumulative probability of nest survival over the nesting period of 0.44.

## Discussion

This contribution is the first and most complete reproductive study on the Cinereous and Long-winged Harriers of South America’s southern cone and represents the southernmost breeding site for Long-winged Harriers. Clutch initiation of both harriers during the breeding season was definitively not synchronised across breeding pairs, moving back or forth only up to a couple of weeks between years. For both species, egg-laying was spread over more than 2 months (see also Millon *et al.* 2002; Terraube *et al.* 2009). Even with the extreme seasonality of weather in the study area, and consequently the variation in resources availability, some breeding pairs were able to begin a new nest in January (while others were with fledglings since December), evidencing a noticeable between-subject variability in nest initiation and an extensive breeding



**Figure 1.** Daily nest survival rate (DSR) of Cinereous (*Circus cinereus*) and Long-winged (*C. buffoni*) Harrier nests related to the distance of the nest to the road (A) and the vegetation height above the nest (B) in different periods of the breeding season (15 October: early nests; 1 December: half of the season; and 15 January: late nests).

season (see also Millon *et al.* 2002; Terraube *et al.* 2009; but see Witkowski 1989).

Natural habitats usually contain more nest predators than human-modified landscapes, possibly due to human control of predators in the intensively managed areas (Whittingham and Evans 2004; Sternalski *et al.* 2013; but see Corbacho *et al.* 1997). In our study site, nesting colonies are in a boundary zone between natural (Monte ecoregion) and highly modified (farmlands) habitats along the road, creating an attractive corridor for nest predator dispersion (McClure *et al.* 2015), which might lead to higher nest predation rates relative to adjacent habitats. However, predation rates reported here are within the values for these kinds of raptors and are comparable to most harrier studies

(Corbacho *et al.* 1997; Millon *et al.* 2002; Terraube *et al.* 2009; Sternalski *et al.* 2013).

Late breeders had lower nesting success than early breeders, indicating a potential disadvantage in reproductive success towards the end of the breeding season (Segura and Reboresda 2012; Low *et al.* 2015). Decreasing nest survival with time of breeding has also been observed in other harriers (Corbacho *et al.* 1997; Millon *et al.* 2002). It has been discussed extensively among ornithologists that the negative relationship between nesting success and time of breeding could be due to a direct effect of breeding time (commonly associated with variations in the nest predator community), an effect of quality (individuals with high phenotypic quality breeding early; Verhulst and Nilsson 2008), or a combination of the two. Late breeders may be exposed to higher nest predation rates, as the abundance and activity of nest predators commonly increase with time of breeding (Verhulst and Nilsson 2008). In addition, nest predators in the area could time their own reproduction to the peak abundance of fledglings (December–January appears as the peak of fledgling production, considering all bird species nesting in the area; L.N.S. pers. obs.). Then, pairs that are still incubating or with young chicks late in the season have fewer chances of success.

Nest success was positively related to vegetation height above the nest, which is consistent with other studies of harriers (Vukovich and Ritchison 2006; Limiñana *et al.* 2011). Increased concealment helps to hide and protect nests from predators (Segura *et al.* 2012) and may also protect harrier nests from the intense winds that are common in our study area. Nevertheless, this result should be viewed with caution because it could be a side-effect of sampling bias towards Cinereous Harrier nests, which had lower vegetation cover, on average, than Long-winged Harrier nests.

The mean distance to the road also influenced nest survival, indicating a noticeable negative impact of this type of human construction on harriers' reproductive success. Route edges are typically sites with abundant disturbance (McClure *et al.* 2015), which can attract more predators and facilitate their movements. The increasing area of agricultural landscapes and human constructions worldwide are causing the destruction and fragmentation of natural habitats, leading birds to use suboptimal sites for breeding purposes (McClure *et al.* 2015). Other studies of harriers have also found a negative effect on breeding success when the nesting habitat is disturbed (Corbacho *et al.* 1997; Millon *et al.* 2002; Vukovich and Ritchison 2006, Terraube *et al.* 2009, Hayhow

*et al.* 2013; Alves *et al.* 2014). For example, Sternalski *et al.* (2013) found that agriculture is detrimental to harrier populations because of the direct destruction of nesting colonies, even though agricultural landscapes often provide a greater abundance of prey (Cardador *et al.* 2011). In the same sense, Arroyo *et al.* (2003) reported that combine harvesters can kill harrier nestlings if they are unfledged by harvest time. Harriers in our study area were able to use highly modified environments (see also Vukovich and Ritchison 2006) such as the roadside in the vicinity of intensively cultivated farmland, and still maintain (at least during our short nest monitoring period) breeding success rates that do not threaten their populations. However, these vulnerable and changing breeding habitats can quickly become a trap that may lead to the local extinction of these sensitive species.

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