

Population size, provisioning frequency, flock size and foraging range at the largest known colony of Psittaciformes: the Burrowing Parrots of the north-eastern Patagonian coastal cliffs

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Abstract. We here describe the largest colony of Burrowing Parrots (*Cyanoliseus patagonus*), located in Patagonia, Argentina. Counts during the 2001–02 breeding season showed that the colony extended along 9 km of a sandstone cliff facing the Atlantic Ocean, in the province of Río Negro, Patagonia, Argentina, and contained 51412 burrows, an estimated 37527 of which were active. To our knowledge, this is largest known colony of Psittaciformes. Additionally, 6500 Parrots not attending nestlings were found to be associated with the colony during the 2003–04 breeding season. We monitored activities at nests and movements between nesting and feeding areas. Nestlings were fed 3–6 times daily. Adults travelled in flocks of up to 263 Parrots to the feeding grounds in early mornings; later in the day, they flew in smaller flocks, making 1–4 trips to the feeding grounds. Overall, the most frequent flock size was two, indicating that the pair is the basic social unit during the breeding season. The average flight-speed was 36.9 km h⁻¹. Terrestrial and aerial surveys during the 2003–04 and 2004–05 breeding seasons suggest that Burrowing Parrots performed long daily movements in order to feed in the remaining patches of natural vegetation, travelling 58 and 66 km over the two main routes to the feeding areas. The colony is seriously threatened by human activity, and surrounding habitat is being rapidly transformed to agricultural land. Based on the data presented, we recommend monitoring the colony using detailed counts of numbers of nests, the documentation of the extent of the entire colony, together with data on breeding success, nestling growth and feeding rates. The number of non-breeders associated with the colony should be monitored, and as an additional index of abundance, counts from stationary locations should be continued.

Introduction

Psittaciformes have become one of the most endangered orders of birds. The parrot action plan for 2000–04 (Snyder *et al.* 2000) considered that 29% of parrots worldwide are at some risk of extinction. This situation is even worse when the Neotropics are considered apart: 34% of the species in this region are at risk of global extinction (Snyder *et al.* 2000). The principal sources of threat are loss, fragmentation or degradation of habitat, introduction of exotic species and diseases, persecution and hunting (Snyder *et al.* 2000), and collection of birds for the pet trade (Wright *et al.* 2001). Some key features of the breeding biology of Psittaciformes also contribute to the fragility of the order, including the almost invariable habit of nesting in holes, the commonly monogamous breeding system (Masello *et al.* 2002), and the absence of territorialism beyond the immediate vicinity of the nest, which contributes in several species to conspicuous

colonial breeding systems. In addition, for most parrot species there is still a lack of basic biological data, which are necessary for the identification of specific threats, the monitoring of populations, and the evaluation of the conservation measures to be taken (Masello and Quillfeldt 2002).

Burrowing Parrots (*Cyanoliseus patagonus*) are colonial Psittaciformes. In Argentina, the species occurs from the Andean slopes in the north-west of the country to the Patagonian steppes in the south (Bucher and Rinaldi 1986). Generally, Burrowing Parrots inhabit bushy steppes, marginal xerophyte forests, grassland and farmland but they require sandstone, limestone or earth cliffs where they excavate their nest-burrows. The species is migratory, occupying the breeding colonies some months before laying and leaving them gradually as the young fledge (see Bucher and Rinaldi 1986; Bucher and Rodríguez 1986). Adult Burrowing Parrots excavate their own nest-burrows. The nesting pairs

use burrows that they have dug in previous seasons, but they enlarge the burrows every year. Each burrow is occupied by a single pair. Burrowing Parrots lay one clutch of two to five eggs per year (Masello and Quillfeldt 2002). They have a socially and genetically monogamous breeding system with intensive biparental care (Masello *et al.* 2002, 2004; Masello and Quillfeldt 2003a).

The conservation status of Burrowing Parrots was last studied in the early 1980s (Bucher and Rinaldi 1986). Formerly, they were very common in Argentina, but they are now only regionally abundant (Harris 1998) and have disappeared from large parts of the country (Bucher and Rinaldi 1986). The decline of the species in Argentina is a result of persecution as a pest of crops, conversion of grasslands to croplands, hunting, and trapping for the pet trade (Bucher and Rinaldi 1986). The Chilean subspecies (*Cyanoliseus p. bloxami*), is considered at risk of extinction (Beltrami *et al.* 1995) owing to its drastic decline in numbers.

Burrowing Parrots are officially considered an agricultural pest in Argentina (*National Law of Defence of the Agricultural Production 6704/63*) although the damage to agriculture is a local phenomenon (Bucher and Rinaldi 1986; Bucher 1992). Bucher *et al.* (1987) observed that the diet of Burrowing Parrots comprises mainly wild seeds and fruits of *Geoffroea decorticans*, *Prosopis caldenia*, *P. chilensis* and *P. flexuosa*. In Patagonia, berries of *Empetrum rubrum*, *Lycium* sp. and *Discaria* sp. (Forshaw 1989) and the berries of *Schinus johnstonii* (de la Vega 2003) have been reported as part of their diet. In the north-east of Patagonia, we have observed Burrowing Parrots eating seeds of the Giant Thistle (*Silybum marianum*), the Nodding Thistle (*Carduus thoermeri*), the thistles *Xanthium spinosum* and *X. kravanilesii*, and seeds of other wild plants such as *Avena fatua*, *Rumex crispus*, and berries of wild shrubs such as *Condalia microphylla* (J. F. Masello, P. Quillfeldt, R. Pérez and R. Scofield, unpublished data). Forshaw (1989) also described the habit of Burrowing Parrots of feeding on soft parts of plants, and we observed buds and other soft vegetable matter in crop contents of nestling Burrowing Parrots especially during the first weeks of chick rearing (end of November to mid-December; Masello and Quillfeldt 2004a). Therefore, except for some marginal agricultural areas and discrete events, damage to agriculture is not intense. Despite this, lethal methods of control have been carried out in various years, without objective quantification of real damage and adequate consideration of alternatives and consequences. In the province of Buenos Aires, a study conducted in 2003 to establish a harvesting scheme for Burrowing Parrots as a means of pest control, found them to be scarce in the province of Buenos Aires, north of Sierra de la Ventana: only 26 individuals were found in a first transect of 1000 km (Grilli 2005). Like many other parrot species that are considered pests, the Burrowing Parrot is valued in the pet trade (Guix *et al.* 1997).

The aims of our study were to describe the colony of Burrowing Parrots located in the north-east of Patagonia, Argentina, and to investigate patterns of daily movements to the feeding grounds during the breeding season, patterns of nestling provisioning and flock size. Additionally, we studied the proportion of Burrowing Parrots not attending nestlings but present at the colony during the breeding season. With these data, we aimed to provide a baseline for further monitoring and conservation of this remarkable colony.

Methods

Study area

The study was carried out at the largest colony of Burrowing Parrots, located along 9 km of a sandstone cliff facing Atlantic Ocean (41°04'S, 62°50'W), 3 km west of the mouth of the Río Negro River, 30 km south-east of Viedma, on the Atlantic coast of the province of Río Negro, Patagonia, Argentina (Fig. 1). Birds in the colony are the nominate subspecies *Cyanoliseus p. patagonus* (Vieillot).

Angulo and Casamiquela (1982) described the geology of the cliff containing the Burrowing Parrot colony. The easternmost part of the cliff is mainly composed of soft sandstone, whereas the westernmost part contains a very compact layer of clay at the bottom, 9–10 m deep, and not used by the Parrots, and layers of soft sandstone on top. The sandstone layers of the westernmost part are similar to those of the easternmost part, and correspond to the same geological feature: the Río Negro Formation.

The habitat surrounding the colony corresponds to the north-eastern Patagonian sector of the phytogeographical province of 'Monte' (Cabrera 1971), characterised by bushy steppes and marginal xerophyte forests. The land surrounding the colony is used for crop production and low-density cattle grazing. Precipitation is the main limiting factor of primary production in arid and semi-arid zones like the Patagonian steppe.

We used, according to accessibility, a sector of the easternmost kilometre of the colony for detailed studies (see e.g. Masello *et al.* 2001, 2002, 2004; Masello and Quillfeldt 2002, 2003a, 2004a, 2004b). Throughout the paper we call this sector of the colony the study sector. The study sector is 30 m long, 25 m high and contains about 500 nests. A total of 96 to 109 nests, according to accessibility, were monitored in the study sector by direct observation through climbing the cliff. The number of nests monitored varied between years owing to the collapse of nests and parts of the cliff, which occurs frequently in the easternmost part of the colony. We could not find a suitable place for monitoring nests in more westerly sectors of the colony, mainly because in the very few suitable sectors for safe climbing, the density of nests is too low to obtain a representative sample. In addition, most sectors of the colony can be accessed only during the few hours in which the low tide exposes a sector of beach.

Nest-counts and description of nests

The number of nest-entrances in the entire 9 km of the colony was counted from photographs taken in January 2002 (2001–02 breeding season). For the easternmost 4.2 km, the densest part of the colony, a complete series of photographs was taken (58 photographs). For the westernmost 4.8 km of the colony, where nests are sparser, sample photographs were taken every 450 m, and the total number of nests in the 450-m sector was extrapolated from these samples. This could be done because in this sector nests are distributed homogeneously and each photograph was representative of the sector considered. Along the westernmost 4.8 km, most nests are in a line following a soft sandstone stratum of the cliff from the bottom of the cliff, i.e. between 14 and 17 m above the sea level (see also Angulo and Casamiquela 1982). A scale was included in every picture, in order to calculate the length of each

sector and the height of the cliff. Overlapping parts of the photographs of the easternmost 4.2 km were counted only once. We used the data of the study sector to estimate the percentage of nest-entrances that correspond to active nests in the entire colony. We expect the quality between habitat patches to be similar in all parts of the colony, and the differences in density caused by the distribution of layers of different softness. We assumed that the different sectors of the cliff are equally suitable for the Parrots for the following reasons: (1) Parrots use sandstone layers of similar geological characteristics and belonging to the same geological formation both in the east and west of the colony; (2) the surrounding habitat is identical; and (3) the regime of tides does not differ noticeably between east and west. The only factor that differs noticeably between parts of the colony is the degree of human disturbance by beach tourists, which is highest in the easternmost parts. The present methodology could therefore underestimate breeding success in the colony because the study site is subject to human disturbance during the last 2 weeks of the nestling period.

In order to test the accuracy of our nests-counts from photographs, we compared data from photographs with direct counts. This test was carried out in the 30-m study sector in January 1999. In the study sector, direct counts recorded 531 nest-entrances whereas counts from photographs recorded 532 nest-entrances, with the difference of 1 in 532 nest-entrances validating the precision of our counts from photographs.

In order to describe the dimensions and shape of Burrowing Parrot nests, 40 nests were selected in the study sector at 4–16.5 m above sea level. Nest-entrances were measured with a rule, and nest-depth measured with a telescopic stick.

Provisioning activity data

During December 2001, provisioning activity patterns were determined using a video system consisting of a black-and-white miniature camera (charge couple device, CCD), with six infrared light emitting diodes (LEDs) as the light source, and a built-in microphone (see Masello *et*

al. 2001). The video system was placed in the entrance-tunnel and directed toward the nest-chamber. Owing to the small size of the unit the nests-entrances did not need to be modified in any way.

In the study sector, three nests at heights of 12 to 16.5 m were selected in order to record provisioning activity (Table 1). Nests with a clear view of the nest-chamber were selected according to accessibility. Provisioning activity was recorded during 4 days at the first nest (12, 13, 14 and 18 Dec. 2001) and the second nest (19–22 Dec. 2001) and during 3 days at the third nest (24–26 Dec. 2001). Further recording was not possible because the video system broke down during heavy rain. All recordings were done close to the time when nestlings reach peak mass (i.e. maximum demand for food), in nests with brood-sizes close to the mean brood-size for that period in order to allow comparisons between nests (see Masello and Quillfeldt 2002). All other monitoring activities in the study sector were suspended during recordings in order to avoid possible disturbance of provisioning activities. For the same reason, recordings were done only during days without the presence of tourists on the beach that forms below the colony during low tide. Tourists usually avoid the sector in days with the occurrence of high tides late in the morning, at noon or in the afternoon. This allowed us to record 3–4 days per week. No recording was made between 2200 hours and 0400 hours of the next day because there was no flight activity at the colony during that period of time. During the recordings, sunrise occurred between 0534 hours and 0539 hours, while sunset occurred between 2038 hours and 2045 hours. Videos were analysed using a high-resolution monitor that allowed us to have a clear view of the entire brood and the adults attending the nest. The following parameters were recorded: the time of adult arrival, the time of adult departure and whether feeding of the nestlings occurred.

Daily movements derived from counts

From the colony at El C ndor, Burrowing Parrots used two main flight-routes to the feeding areas, one to the north-east of the colony and the

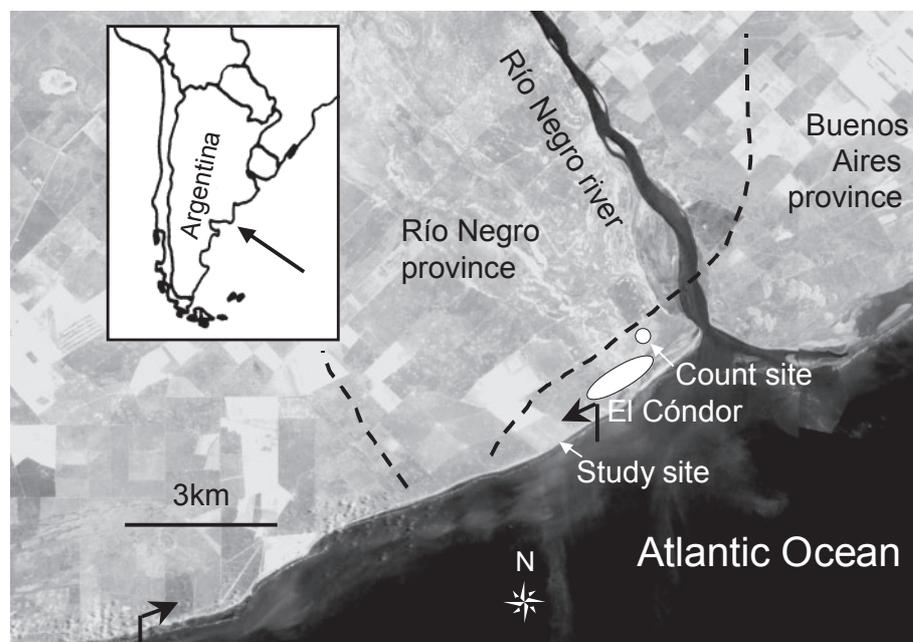


Fig. 1. Location of the Burrowing Parrot colony and the study sites at El C ndor, Patagonia, Argentina. The arrow in the small map shows the location of El C ndor. The Burrowing Parrot colony extends between the arrows in the larger map. White circle: site of the counts of Parrots flying to the feeding areas; dashed lines: flying routes to the feeding areas. Satellite image adapted from http://www.conae.gov.ar/dispa/2000/ARG_index.html (accessed 23 January 2006).

second to the north-west (Fig. 1). We recorded flight activity in the north-easterly route, in which the Parrots cross the Río Negro River in the direction of the Buenos Aires Province, on the 2, 16 and 23 December 2001. Dates were chosen during the period of maximum nestling provisioning activity (i.e. all the nestlings in the study sector had already hatched but none had yet fledged). During the census, sunrise occurred between 0534 hours and 0537 hours, and sunset between 2028 hours and 2044 hours.

By the use of binoculars, observations were carried out from the top of a hill (6 m high) with a clear 360° view of the surrounding area. Counts were carried out from 0400 hours to 2100 hours on each of the census days. We divided each period into 15-min intervals, during which we counted all birds flying on the north-western side of the hill (facing inland; see Fig. 1) for 5 min, then all the birds flying on the south-eastern of the hill (facing seawards; see Fig. 1) for the next 5 min, and then had a rest for 5 min. During the first 5 min of each interval, we recorded the number of Parrots, the flock sizes and the flight direction in a view of 180° towards the sea. Tests of inter-observer reliability revealed that flock-size was simple to distinguish.

Flight-speed

Flight-speed was calculated by measuring, with a stopwatch, the time a Parrot took to fly 100 m (i.e. the distance between two posts along a power line). Such suitable reference points were available along a sector of the north-easterly route (Fig. 1), and measurements of flight-speed were taken only from birds returning from the feeding places to the colony. Wind direction was determined close to the posts of power lines, with the use of a compass, during the measurements of flight-speed.

Daily flights to the feeding areas

On 1 January 2004, 16 December 2004 and 6, 7, 10 and 11 January 2005 we searched exhaustively for feeding flocks of Burrowing Parrots around the colony, in the north-eastern sector of the Adolfo Alsina Department, in the province of Río Negro, and the southern sector of the Patagones Department, in the province of Buenos Aires. This area of ~1400 km² has only three roads and a few accessible tracks. The land is privately owned and permission of the landowners is necessary for entering the fields. All the area along each road and track was surveyed. An average of 120 km of roads and tracks were covered at low speed (~30 km h⁻¹) in each of the surveys. Surveys were carried out from sunrise to sunset, with the same roads and tracks surveyed at different times of the day on different survey days, in particular covering those times of the day when most flight activity occurred. Observations were carried out by two observers at any time, each covering a 180° view to the right and left side of the vehicle. Flocks of Parrot were easily detected in this flat and almost treeless area. We stopped whenever Parrots were seen and observations from the border of the roads and tracks were carried out with the use of binoculars and a telescope (×60).

On 6 January 2005, we conducted an aerial survey of the 1400-km² area mentioned above. Observations were carried out from a Cessna 182, at an altitude of 150 m and an average speed of 240 km h⁻¹. The total linear distance covered was 400 km and the plane was flown first from east to west, then from south to north and from west to east, so that

the north-easterly and north-westerly feeding routes were always in sight. Observations were carried out by two of us (J. F. M., P. Q.), each covering a 180° view to the right and left side of the plane. We recorded the number of Parrots, the flock sizes and the flight direction. The locations of feeding flocks of Burrowing Parrots and their linear distance to the colony at El Cóndor were calculated with the use of a global positioning system (GPS, Geko 201, Garmin).

Estimation of the number of non-breeders attending the colony

Through the use of the video system in the 2001–02 breeding season, we learnt that breeding pairs of Burrowing Parrots spend the night with their young in the nest during the nestling period. These first observations from the video recordings were confirmed by direct inspection of nests in the study sector, by climbing to the nests during the late evening in the 2003–04 breeding season. Thus, Burrowing Parrots that roost outside of nests during the nestling period were not attending nestlings. Between the end of November and the end of December, flocks of Burrowing Parrots spend the night (2100 to 0330 hours) in the village of El Cóndor, roosting mainly on power lines. The village of El Cóndor and its peripheral streets are the only roosting place of Burrowing Parrots associated with the colony in a radius of 30 km. On two nights in December 2003 (2 and 22 Dec.), a team of six trained people, in two vehicles, counted all Burrowing Parrots in the village of El Cóndor between 2100 and 2200 hours (i.e. at dusk: sunset 2028 hours and 2044 hours on 2 and 22 Dec. respectively; astronomical twilight 2230 and 2251 hours). Light conditions in these two days were good and torches were not needed. At dusk, Burrowing Parrots are usually not observed on the steppes surrounding either the colony or the village of El Cóndor. The counts were done after the time of hatching of late broods (see Masello and Quillfeldt 2002) and well before the first sightings of fledglings outside their burrows on 29 December 2003. All the counted Parrots were thus close to the beginning of their second year of life or older. Tests of inter-observer reliability revealed that roosting birds were simple to count, i.e. counts from different observers were the same. No further counts were possible.

Throughout this study, all means are given ± s.e.

Results

Nest-counts and description of nests

Counts during the 2001–02 breeding season revealed that the colony extended along 9 km of a sandstone cliff facing the Atlantic Ocean, in the province of Río Negro (Fig. 1), the height of the cliffs where the colony was located ranging from 11 to 27 m high above sea level. Nests were found in layers of soft sandstone between 3 m above the average level of high tide and 0.5 m from the top of the cliff. No nests were found in the compact layer of about 9 m of clay at the bottom of the westernmost 5 km of the colony. The total number of nest-entrances counted along the 9 km of the colony was 53

Table 1. Provisioning activity of Burrowing Parrots in three nests recorded during December 2001 at El Cóndor, Río Negro, Patagonia, Argentina

Two nests contained a brood of three nestlings; the third had a brood size of four

	Time of day								
	0400–0559	0600–0759	0800–0959	1000–1159	1200–1359	1400–1559	1600–1759	1800–1959	2000–2159
Total feeding events	9	1	1	6	4	1	1	6	3
Total observed periods	9	8	7	8	7	7	7	8	8
Probability of feeding	100%	12.5%	14.3%	75%	57.1%	14.3%	14.3%	75%	37.5%

443. In the study sector, 96.2% of inspected burrows had one entrance, and 3.8% had two entrances. Assuming that the proportion of burrows to nest-entrances is homogeneous within the colony, we estimated the total number of burrows in the entire colony as 51 412 burrows (53 443 counted nest-entrances \times 0.962). The distribution of burrows in the colony is shown in Fig. 2. The 4 km at the eastern end of the colony are more densely populated than the remaining 5 km (Fig. 2). The compact clay layer in the westernmost seems not to be suitable for the Parrots, as no nest-entrances were observed in it, and this structural difference of the cliff (i.e. more soft sandstone layers in the east than in the west of the colony) appears to be the main factor affecting the distribution of nests in the cliff.

During our studies we found that the proportion of inspected burrows that were active (i.e. contained eggs or nestlings) in the study sector was 94% in the 1998–99 breeding season ($n = 68$ burrows checked for eggs; Masello and Quillfeldt 2004b), 85% in 1999–2000 ($n = 79$ burrows; Masello and Quillfeldt 2002), 73% in 2001–02 ($n = 109$ burrows), 62% in 2003–04 ($n = 96$ burrows), and 57% in 2004–05 ($n = 79$ burrows). The remaining nests were inactive or were not habitable owing to collapsed walls. The proportions of collapsed nests was 2% in the 1998–99 breeding season ($n = 68$ burrows checked for eggs; Masello and Quillfeldt 2004b), 5% in 1999–2000 ($n = 79$; Masello and Quillfeldt 2002), 10% in 2001–02 ($n = 109$ burrows), 20% in 2003–04 ($n = 96$ burrows), and 10% in 2004–05 ($n = 79$ burrows). If the proportion of active nests was homogeneous in the entire colony, the total number of active nests is estimated to be 37 527 active nests in the 2001–02 breeding season.

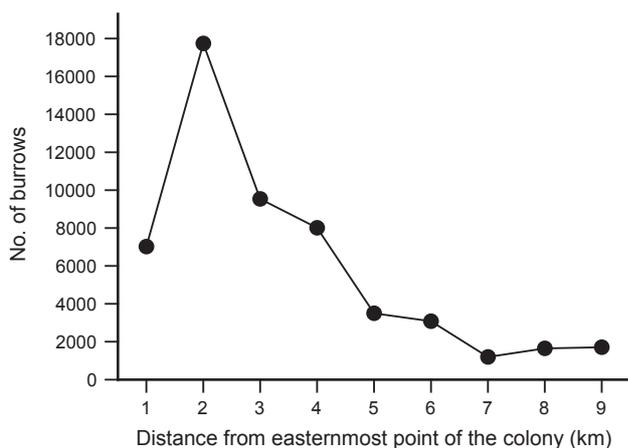


Fig. 2. Number of Burrowing Parrots burrows per kilometre at the colony in El Cóndor, Patagonia, Argentina. The number of nest-entrances in the entire colony was counted from photographs taken in January 2002. For the easternmost 4.2 km, the densest part of the colony, a complete series of photographs was taken (58 photographs). For the remaining 4.8 km of the colony, where nests are sparser, sample photographs were taken every 450 m, and the total number of nests in the 450-m sector was extrapolated from these samples.

The burrows are depressed cylinders dug in the softest layers of sandstone. Many burrows are rectilinear, and the direction approximately orthogonal to the cliff-face, although burrows inclined to the cliff-face and J-shaped burrows are quite common. More complex structures also occur. Some burrows have two entrances leading to a single nest-chamber (see above) and occasionally single entrances lead to two nest-chambers, although only rarely do the latter contain two broods. The burrows follow the stratification of the cliff. The nest-entrances are elliptical, with the major axis horizontal (mean width 26.4 ± 1.3 cm, range 14–49 cm, $n = 40$) and the minor axis vertical (mean height 12.9 ± 0.6 cm, range 8–25 cm, $n = 40$). Most of the burrows are about 1.5 m deep, but vary from 0.6 m to more than 3.5 m. The nest chamber is about the same width as the nest-tunnel but is higher because the Parrots dig a shallow cavity in which the eggs are laid and nestlings are raised.

Provisioning activity data

During December 2001, nestlings were fed between three and six times per day. In all three monitored nests and observation days, both adults stayed in the nest overnight ($n = 3$, 3 and 2 nights; see Table 1). The arrival time of adults for the night ranged between 1832 and 2043 hours ($n = 8$ evenings; see also Table 1). The mean arrival times of adults for the night in each of the three observed nests were 2002 hours \pm 0.20 h ($n = 3$ nights), 1922 hours \pm 0.30 h ($n = 3$) and 1958 hours \pm 0.19 h ($n = 2$). The arrival of the adults in the evening was always followed by feeding of the nestlings ($n = 8$ evenings; see Table 1). All nestlings were fed again in the early morning, before the adults left the nest ($n = 9$ mornings; see Table 1). Time of morning departure of adults ranged from 0506 to 0624 hours (mean departure times for each of the three nests: 0605 hours \pm 0.11 h ($n = 3$ mornings); 0515 hours \pm 0.04 h ($n = 4$); and 0544 hours \pm 0.12 h ($n = 2$)). Adult Parrots returned to the nests during the morning between 0902 and 1217 hours (mean time outside the nest during the morning hours: 4 h 56 min \pm 24 min ($n = 3$ mornings); 5 h 51 min \pm 1.05 h ($n = 3$); and 5 h 3 min \pm 0.21 h ($n = 2$)). There was a peak of feeding activity between 1000 and 1200 hours, when 75% of the pairs returned to feed the nestlings (Table 1). Feeding activity was less synchronous during the afternoon. All recorded departures from ($n = 27$) and arrivals at ($n = 29$) the nest, except for one departure, were by both parents.

Daily movements and flock-sizes from counts

In line with the departure time of adults observed in the video recordings during December 2001, the counts on the 2, 16 and 23 December 2001 show that there was a pronounced peak in numbers of adults flying to the feeding places at 0500–0600 hours, and a peak in numbers of adults flying back to the colony at 0900–1000 hours (Fig. 3). In the afternoon, no such pronounced peaks in movements were

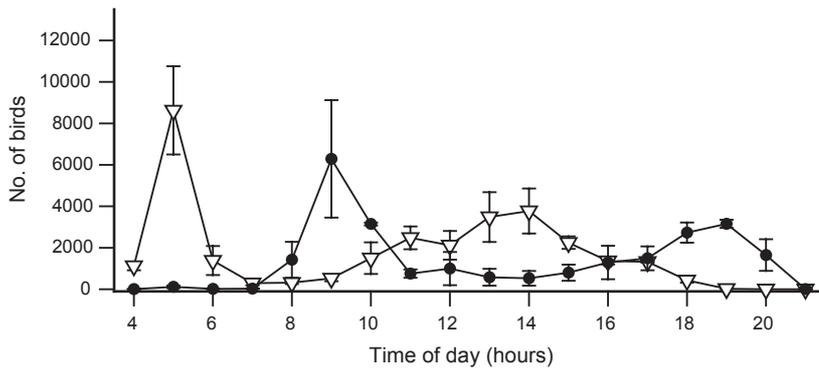


Fig. 3. Mean number of Burrowing Parrots (\pm s.e.) flying to the feeding places (Δ) or back to the colony (\bullet) at El Cónдор. Counts were carried out on 2, 16 and 23 December 2001 on the north-easterly route to the feeding places (see also Fig. 1).

observed (Fig. 3). From 1800 hours very few individuals were observed flying to the feeding places (Fig. 3).

Burrowing Parrots formed flocks only with conspecifics, comprising up to 263 individuals ($n = 16085$ flocks over 51 h in 3 days of observations), though the most frequently occurring flock-size was two (Fig. 4). Single Burrowing Parrots were also observed flying to the feeding grounds (Fig. 4). Mean flock-size showed a maximum at 0400–0500 hours, during the departure time from the colony, and rapidly decreased between 0500 and 0700 hours, and remained low throughout the rest of the day (Fig. 5).

Flight-speed and daily flights to the feeding areas

The mean flight-speed of adults between the colony and the feeding places was 36.9 ± 1.7 km h⁻¹ ($n = 25$), and varied with wind direction (against wind: 28.8 ± 1.6 km h⁻¹, range 23.9–35.8 km h⁻¹, $n = 7$; no wind: 37.0 ± 1.6 km h⁻¹, range 31.5–48.3 km h⁻¹, $n = 13$; tail wind: 48.0 ± 2.1 km h⁻¹, range 41.9–53.3 km h⁻¹, $n = 5$).

During the aerial survey carried out on 6 January 2005 (2004–05 breeding season), most feeding flocks of

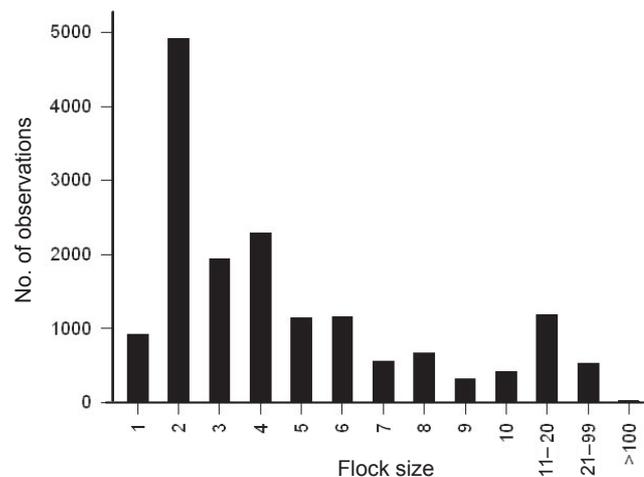


Fig. 4. Frequency of occurrence of different flock sizes of Burrowing Parrots. Counts correspond to Parrots flying to and from the feeding places on 2, 16 and 23 December 2001 on the north-easterly route (see also Fig. 1).

Burrowing Parrots were found in patches of natural vegetation (Table 2), at distances of up to 66 km from the study site.

Combining the observations from terrestrial and aerial surveys, feeding flocks of Burrowing Parrots were found along the north-easterly flight-route, at distances ranging from 35 to 58 km from the study site, whereas feeding flocks along the north-westerly route were found at distances ranging from 26 to 66 km from the study site (see Fig. 1, Table 2). These observed ranges correspond to the two large remaining patches of natural vegetation, one at the end of the north-easterly route (at 40°38'S, 63°15'W) and another one at the end of the north-westerly route (40°57'S, 63°11'W).

Estimation of the number of non-breeders attending the colony

We counted 6671 Burrowing Parrots roosting in the village of El Cónдор on 2 December 2003 and 6270 on 22 December 2003, mainly on power lines. These figures represent an average of 6471 non-breeders associated with the colony. These non-breeders may have been birds that had attempted to breed but had failed, birds that had not yet attempted to breed, or young birds digging nests to be used in later breeding seasons (J. F. Masello, personal observation).

Discussion

In the present study, we describe the largest known colony of Burrowing Parrots and present data on provisioning rhythms

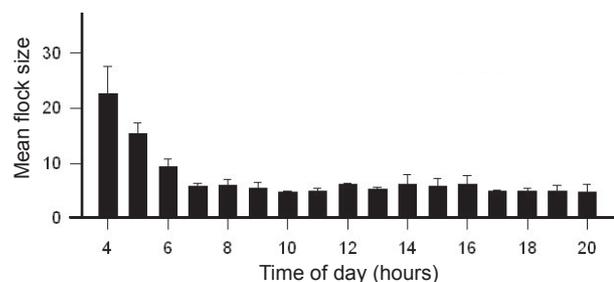


Fig. 5. Daily variation of mean flock size of adult Burrowing Parrots on the north-easterly route between the colony at El Cónдор and the feeding places on 2, 16 and 23 December 2001. Sample sizes per hour ranged from 89 to 1912 flocks of Burrowing Parrots.

by breeding birds, the sizes of foraging flocks during the breeding season, the daily flights to the feeding areas and the number of non-breeders associated with the colony. With these data, we provide a baseline for the monitoring and conservation of this important parrot colony. Remarkably, after an extensive literature review, to our knowledge this population is the largest known colony for the entire order Psittaciformes. During the 2001–02 breeding season we found that the colony extended along 9 km of a sandstone cliff facing the Atlantic Ocean, in the province of Río Negro, Patagonia, Argentina, and contained 51412 burrows, of which an estimated 37527 were active (Figs 1, 2).

Provisioning activity pattern

Food availability for Burrowing Parrots varies both in time and space, and the birds have evolved behavioural mechanisms to cope with fluctuations in food supply, which include flexible time-budgets in adults, and flexible growth rates in chicks. For example, poorly fed chicks of Burrowing Parrots during drought may retard growth processes in response to dietary restrictions (Masello and Quillfeldt 2004b). As a result, they may still fledge successfully despite severe food shortages during their development, and breeding success alone would poorly describe the quality of the season. Therefore, chick-growth and feeding rates are important parameters for monitoring.

In the present study, we found that adult Burrowing Parrots fed their nestlings between three and six times a day with a pronounced peak of feeding activity during the morning (Table 1). Adults always fed the nestlings after arrival at the nests in the evening and before departure early in the morning. Adult Burrowing Parrots spent the night in the nest with their nestlings. The feeding frequencies observed in Burrowing Parrots are in line with other psittaciform species (e.g. Rinke 1989; Rowley 1990; Waltman and Beissinger 1992; Wermundsen 1998; Krebs *et al.* 1999; Renton and Salinas-Melgoza 1999; Siegel *et al.* 1999).

In the studied colony we found a peak in numbers of Burrowing Parrots flying to the feeding places immediately after sunrise, and a peak in numbers returning to the colony about 4 h later. Flying activity in the afternoon showed no such synchronization (Fig. 3). Parrots not attending nestlings but roosting in the village of El Cóndor during the night may

join breeding birds flying to the feeding grounds and contribute to the morning peak of flight activity. A common pattern of daily activity in Psittaciformes consists of an active period that begins at sunrise and lasts several hours, followed during the middle of the day by a period of inactivity (e.g. Cook *et al.* 1984; Boussekey *et al.* 1991; Rowley and Chapman 1991; Pitter and Christiansen 1995; Skead 1964; Wirminghaus *et al.* 2001) or a period of reduced activity (e.g. Hardy 1965; Roth 1984; Loyn *et al.* 1986; Brandt and Machado 1990; Emison and Nicholls 1992; Emison *et al.* 1994; Pizo *et al.* 1997; Hampe 1998), before recommencing activity a few hours before sunset through until sunset. In most studies, the decrease or break in activity appears to occur round the hottest part of the day and is related to the need to avoid activities requiring elevated metabolic rates in that period (see Wyndham 1980; Westcott and Cockburn 1988; Gilardi and Munn 1998). The relatively mild temperatures during December in north-eastern Patagonia (daily maximum temperatures $27.1 \pm 0.3^\circ\text{C}$, $n = 9$ years, in the 1990s), compared with those in habitats of other parrot species, could be a reason for the activity observed at El Cóndor during midday and the afternoon (Fig. 3). Alternatively, the observed pattern of activity may be related to a relatively low or sparsely distributed food supply in the Patagonian steppes forcing the birds to forage throughout the day.

Flock sizes

Counts of commuting birds from stationary locations can provide useful monitoring data, particularly if stations are established along important flight-lines (Snyder *et al.* 2000). Such counts are often most useful as indices of abundance if carried out over long periods of time (Snyder *et al.* 2000).

The most frequently occurring flock size was two (Fig. 4), indicating that the pair is the basic social unit during the breeding season, although we observed monospecific flocks of up to 263 Parrots. The largest flocks were observed immediately after sunrise (Fig. 5).

Parrots show great variation in flock sizes between species (e.g. Wyndham 1980; Beeton 1985; Emison and Nicholls 1992; Emison *et al.* 1994; Pizo *et al.* 1995) although the primary social unit appears to be the pair, or pairs with additional individuals that are likely to be young of the year (e.g. Cannon 1984; Boussekey *et al.* 1991; Chapman *et al.*

Table 2. Data from flocks of Burrowing Parrots observed during the aerial survey (6 January 2005) and six terrestrial surveys (1 January 2004, 16 December 2004 and 6, 7, 10, 11 January 2005) carried out in the north-eastern sector of the Adolfo Alsina Department, in the province of Río Negro, and the southern sector of the Patagones Department, in the province of Buenos Aires, Argentina

	Minimum distance to the colony (km)	Maximum distance to the colony (km)	Total number of Burrowing Parrot flocks	Median size of flocks	Range of flock sizes	Number of flocks in patches of natural vegetation	Number of flocks in pastures	Number of flocks close to crops
Aerial survey	31	66	23	16	2–100	18	4	1
Terrestrial surveys	26	58	49	8	3–49	46	2	1

1993; Wilson 1993; Toyne and Flanagan 1997; Gilardi and Munn 1998; Wirminghaus *et al.* 2000). Burrowing Parrots are among the species in which large flocks are common (Bucher and Rinaldi 1986; Forshaw 1989; present study). A number of hypotheses have been put forward to explain variation in flock-sizes, some of which focus on the distribution of food (see Cannon 1984; Rowley and Chapman 1991; Pitter and Christiansen 1995; Pizo *et al.* 1995; Gilardi and Munn 1998; Wermundsen 1998), some on the degree of aridity (Brereton 1971; Cannon 1984), some on the level of feeding competition (Chapman *et al.* 1989) and others on predation (Westcott and Cockburn 1988).

The large flocks observed in our study during early mornings (see also Bucher and Rinaldi 1986; Forshaw 1989), together with the aridity of the region around the Burrowing Parrot colony at El C ndor, are in line with the hypothesis of aridity as a determinant of flock-size, although (see Brereton 1971 and Cannon 1984), as in many other parrot species, the pair is the basic social unit. Further studies on flock-size outside the breeding season would be necessary to test adequately the hypothesis of aridity as a determinant of flock-size in Burrowing Parrots. But for this it would be necessary first to discover the wintering places, which are still unknown.

Daily flights to the feeding areas

Any attempt to protect the colony properly requires a good knowledge of the foraging needs of this population, and the identification and protection of the feeding areas that support the population.

Our results suggest that Burrowing Parrots at El C ndor may perform long daily movements in order to reach the remaining large patches of natural vegetation. The combined results of the terrestrial and aerial surveys during the 2003–04 and 2004–05 breeding seasons showed that feeding flocks of Burrowing Parrots were found at maximum distances of 58 km (on the north-easterly route) and 66 km (on the north-westerly route) from the study site (Fig. 1, Table 2). Sixty-four feeding flocks were located in patches of natural vegetation (see Methods), six were found in pastures, and only two were located close to crops in an irrigated area. Although most of the observed feeding flocks were small, supporting an earlier observation that the Burrowing Parrots disperse in small flocks to feed in patches of natural vegetation (Forshaw 1978), we also observed several large feeding flocks up to 100 individuals on both routes. Given an average flight-speed of 37 km h⁻¹ and distances to the feeding places of up to 66 km, the birds may spend a considerable part of each feeding trip commuting. One factor undoubtedly influential in determining the daily movements observed in these Parrots is the nature and distribution of their food resources. Species exploiting ephemeral or widely dispersed food resources may be forced to travel long distances to find suitable feeding locations (e.g. Benson *et al.* 1988; Duarte da Rocha *et al.* 1988).

Threats to the colony and the necessity of monitoring

The extraordinary size of this colony has not been described until now, although Yorio and Harris (1997) estimated that the colony extended between 5 and 10 km along the cliffs. The importance of the colony has so far been largely overlooked, and the colony has no legal protection at present.

The number of threats is large, and some are difficult to control. The major threat to the feeding areas frequented by the Burrowing Parrot is the clearance of natural vegetation. The annual rate of clearance of the native vegetation has been estimated at 3.7% (departments of Adolfo Alsina, in the province of R o Negro, and Patagones, in the province of Buenos Aires; Pezzola *et al.* 2004). In addition, large sectors of the steppes are burnt every year, supposedly in order to protect private property from natural fires. At the top of the cliff supporting the colony of Burrowing Parrots, vegetation is cleared annually with the use of heavy machinery. This, combined with the burning of the margins of the road that runs along the top of the cliff, leads to much erosion in some sections and poses a serious threat to the stability of parts of the cliff supporting the colony. Rain often falls in the form of violent thunderstorms and areas of soil unprotected by vegetation are easily washed away.

In addition, the colony itself has been seriously threatened during the last 25 years, by: poisoning in parts of the colony in an attempt to reduce the number of Parrots; infrastructure works, including dynamiting a section of the colony to allow building of pedestrian and car access close to the beach below the cliff; disturbance from cars along the beach below the cliff; unrestricted paragliding; trapping for the pet trade; and shooting of adult Burrowing Parrots bringing food to the nestlings by tourists (see also Masello and Quillfeldt 2003b, 2004c).

Yorio and Harris (1997) reported that the highest densities of nests were observed in the easternmost kilometre of the Burrowing Parrot colony at El C ndor. During the first years of our study (1998–2000), we observed the same pattern (e.g. Masello and Quillfeldt 2002). Present data show that the maximum densities are no longer along the easternmost kilometre (Fig. 2). The densest sector now corresponds to the second easternmost kilometre of the colony (Fig. 2). This apparent displacement of birds could be related to high levels of human disturbance in the easternmost kilometre of the colony: the expansion of the village towards the colony with the last buildings now less than 30 m from the first nests of the sector (in 1998 buildings were ~400 m away); the building of the car access and car parking carried out in 2000–01; and the subsequent process of strong erosion, the commercial extraction of sand, intense poaching activity in 2002–03, and intense paragliding activity since 2001. All these activities affect mainly the easternmost kilometre of the colony.

The colony should be closely monitored in future years until legal protection can be achieved or a conservation management plan reduces pressure from holidaymakers.

Conclusions

We have identified parameters for subsequent monitoring of the colony, in order to determine population trends or to measure progress in conservation efforts. At the colony, the most imminent threats are the impact of the expanding nearby village, including the access road to the beach, and the diverse holiday activities taking place only metres from the nests. We recommend regular annual population studies of this colony along its entire extent, including formal, regular population estimates, studies of breeding success, chick growth and feeding rates (see Masello and Quillfeldt 2002, 2004b) and measurement of recruitment and loss from the colony. The number of non-breeders associated with the colony should also be monitored, and as an additional index of abundance, counts from stationary locations should be continued. Radio-tracking of breeding adults, in order to determine precisely the feeding areas, and of fledglings, in order to estimate survival data, should be carried out.

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