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BREEDING BIOLOGY OF THE BURROWING PARROT *CYANOLISEUS PATAGONUS* AT THE THIRD LARGEST COLONY IN NORTHERN ARGENTINE PATAGONIA

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Abstract · Data on reproductive parameters from different populations of a species may elucidate variations in reproductive strategies, and identify factors affecting local populations. We present data on reproductive biology of the Burrowing Parrot *Cyanoliseus patagonus* from a poorly studied colony at Las Grutas, in Río Negro, northern Argentine Patagonia. We estimated colony size, and over two breeding seasons in 2019–2020 and 2021–2022, we inspected 46 and 82 nests to determine reproductive parameters of clutch and brood size, hatching success, nestling survival, and nest success. We recorded 960 burrowing parrots in the colony. Mean clutch and brood sizes were 3.2 ± 1.3 eggs and 2.8 ± 1.2 nestlings in 2019, and a lower 2.8 ± 1.3 eggs and 1.6 ± 1.6 nestlings in 2021. Hatching success and nestling survival were also higher during 2019–2020 with 81.3% and 63.4% respectively, whereas in the 2021–2022 season there was 64.1% hatching success and 40.6% nestling survival. Apparent nest success was higher in 2019–2020 with 80.4% of the nests fledging at least one chick, against 51.2% for the 2021–2022 breeding season. Hatching failure and brood reductions were observed during both seasons, as well as nest abandonment, which was more pronounced during the 2021–2022 breeding season. Our data suggest that the Las Grutas colony has remained stable over the last 16 years. The reproductive parameters observed in the present study are lower than for the large El Condor population, but similar to an urban colony in southern Buenos Aires Province.

Resumen · Biología reproductiva del loro barranquero *Cyanoliseus patagonus* en la tercer colonia más grande en el norte de la Patagonia Argentina.
Los datos sobre parámetros reproductivos de diferentes poblaciones de una especie pueden ayudar a esclarecer variaciones en las estrategias reproductivas e identificar factores que afectan a las poblaciones locales. Presentamos información sobre la biología reproductiva del loro barranquero *Cyanoliseus patagonus* en una colonia poco estudiada ubicada en Las Grutas, en Río Negro, al norte de la Patagonia Argentina. Estimamos el tamaño de la colonia y, durante dos temporadas reproductivas (2019–2020 y 2021–2022), inspeccionamos 46 y 82 nidos para determinar parámetros reproductivos como el tamaño de puesta, número de pichones, el éxito de eclosión, la supervivencia de los pichones y el éxito aparente de anidación. Registramos 960 loros barranqueros en la colonia. Los tamaños promedio de puesta y pichones fueron 3,2 ± 1,3 huevos y 2,8 ± 1,2 pichones en 2019, y 2,8 ± 1,3 huevos y 1,6 ± 1,6 pichones en 2021. El éxito de eclosión y la supervivencia de los pichones fueron mayores durante 2019–2020, con un 81,3% y 63,4%, respectivamente, mientras que en la temporada 2021–2022 estos valores fueron del 64,1% y 40,6%. El éxito aparente de anidación fue más alto en 2019–2020, con un 80,4% de los nidos produciendo al menos un pichón, en comparación con el 51,2% en la temporada reproductiva 2021–2022. Se observaron fallos en la eclosión y reducción de nidada durante ambas temporadas, así como abandono de nidos, lo cual fue más pronunciado en la temporada 2021–2022. Nuestros datos sugieren que la colonia de Las Grutas se ha mantenido estable durante los últimos 16 años. Los parámetros reproductivos observados en este estudio son más bajos que los de la gran población de El Cóndor, pero similares a los de una colonia urbana en el sur de la provincia Buenos Aires.

Keywords: *cavity nester · Las Grutas · life history traits · natural history · nesting success*

INTRODUCTION

Data on breeding biology of populations is essential to identify and develop effective conservation measures for threatened and declining species (Green 2004, Snyder 2000). Furthermore, the study of reproductive parameters across the entire distribution of a species may elucidate differing reproductive strategies and identify factors affecting reproduction at a local scale. More than half of all parrot species (order Psittaciformes) are currently undergoing population declines (Birdlife International 2023) mainly due to habitat loss because of anthropogenic land use, and pressure from the international and domestic pet trade (Olah et al. 2016, Berkunsky et al. 2017, Donald et al. 2024).

One such species is the Burrowing Parrot, *Cyanoliseus patagonus*, which has undergone a retraction in distribution since the early 19th century (Moschione & González 2005, Rojas Martinez 2008, Masello et al. 2011, Ricci et al. 2018). This is particularly evident in southern Chile, where the Burrowing Parrot no longer occupies coastal cliffs (Ricci et al. 2018), or in the Coquimbo region in the north, where for many years the population was decimated by hunting and the illegal extraction of their offspring for trade (Rojas Martinez

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2008). In Argentina, the northwest populations are in critical conservation status, while those in the southeast remain highly abundant despite enduring significant threats over the years (Moschione & González 2005, Masello et al. 2006, Masello et al. 2011).

Four subspecies of the Burrowing Parrot have been identified through genetic methods: *C. p. bloxami* occurs only in Chile; *C. p. andinus* in northwest Argentina, *C. p. patagonus* in central and southern Argentina, and *C. p. conlara,* considered a hybrid between *patagonus* and *andinus*, in central Argentina (Masello et al. 2011). Two of these subspecies are in a critical conservation status with less than 6000 individuals for *C. p. bloxami* (Rojas Martinez 2008) and 2000 nests for *C. p. andinus* (Moschione & González 2005, Masello et al. 2011). Regarding *C. p. conlara*, Masello et al. (2011) registered a total of 450 nests in the provinces of San Luis and Córdoba. Meanwhile, the more widely distributed subspecies *C. p. patagonus* is estimated to have 43000 nests throughout its range, with reproductive colonies in the provinces of La Pampa, Neuquén, Buenos Aires, Río Negro, and Chubut (Masello et al. 2011, López et al. 2018, Lera et al. 2023a).

Rio Negro holds the greatest number of nests with nine colonies reported for the province (Masello et al. 2011). Approximately 80% of the nests are located in the colony of El Cóndor with 37000 active nests (Masello et al. 2006, Masello & Quillfeldt 2012), which has been studied extensively (Masello et al. 2002, Masello & Quillfeldt 2002, 2004a, b, Masello et al. 2006, 2009). The reproductive success of the El Cóndor colony is among the highest reported for parrots in the wild, with 85% nesting success, and a clutch size of 3.8 ± 0.1 eggs, producing 3 ± 0.2 juveniles per nesting pair (Masello & Quillfeldt 2002). The second largest colony of the species, known as La Lobería, is located near the El Condor colony, and is reported to have a total of 3700 nests (Masello et al. 2011). The colony of Las Grutas is the third largest colony of the province, with 420 nests registered. Unfortunately, for the majority of the colonies of the Río Negro province, with the exception of El Condor, there is a lack of knowledge on breeding parameters other than the number of active nests (Masello et al. 2011).

A few other studies have provided data on nesting success of Burrowing parrots, including urban colonies from the southern corner of Buenos Aires Province, where Lera et al. (2023a) report a maximum productivity of 2.27 ± 0.68 juveniles per breeding pair in the 2022–2023 breeding season, and a minimum of 1.16 ± 0.46 juveniles per breeding pair in 2021–2022. Also, in La Pampa, López et al. (2018) monitored two nests of the species in a novel nest-site of a tree cavity: one nest was abandoned after being taken-over by a pair of Barn Owls *Tyto alba*; and the other nest fledged three chicks. In this study, we present reproductive parameters of the third largest colony of Burrowing parrots in the Rio Negro Province. Our objectives were to (1) update the size of the Burrowing Parrot colony located in Las Grutas, and (2) collect data on the reproductive parameters of Burrowing Parrot nests at the colony.

METHODS

Study site. The study was conducted in the coastal village of Las Grutas, Rio Negro Province, Argentina (Figure 1), included since 1993 in the San Antonio Bay Natural Protected Area. The protected area comprises a zoning system based on allowed uses, from no-take zones to multiple-use areas (Giaccardi & Reyes 2012). We carried out our study in a multiple-use zone that includes human-modified areas of urban settlements, and intensive use activities of port operations, beach tourism, and recreational fishing. Las Grutas is characterized by a sandy beach limited by a sandstone cliff, 5 km long, reaching heights varying from 6–12 m, and represents the highest formation along the coast. This cliff is composed of calcareous, coquinoidal and clayey sandstones in addition to pyroclastic material and abundant gypsum layers (Roque Kokot & Favier-Dubois 2017). The study area has a temperate semi-arid climate with oceanic influence, characterized by an average annual precipitation of 256.5 mm and approximately 270 dry days per year. The wettest seasons are autumn and spring, while the rest of the year is predominantly dry (Genchi et al. 2010). According to data provided by the National Meteorological Service, the annual precipitation values were higher in 2021 compared with 2019 (312 mm vs 248 mm). However, the total amount of precipitation that corresponds to the period before the breeding season (i.e., May to October; Masello & Quillfeldt 2004a) was higher during 2019 in comparison with 2021 (158 mm vs 82.1).

Burrowing Parrot nests are patchily distributed along the cliff, forming a colony of 420 active nests (Masello et al. 2011). One area of the cliff, between 40°48.157'S, 65°04.110'W and 40°48.396'S, 65°04.667'W, has 125 nests, while a larger section with 295 active nests spread along 1 km of cliff occurs between 40°48.655'S, 65°05.206'W and 40°48.909'S, 65°05.580'W (Masello pers. comm.). We focused our study on the larger section of the cliff with more nests.

Parrot nesting cycle. The nesting season of the Burrowing Parrot extends from September to March (Bucher et al. 1987, Masello & Quillfeldt 2002, Vargas-Rodríguez & Squeo 2014). A few months before egg-laying begins, Burrowing parrots arrive at the colony for nest maintenance —either cleaning or enlarging the burrow— and to mate (Masello & Quillfeldt 2012, Vargas-Rodríguez & Squeo 2014). Adult Burrowing Parrots excavate their own cavity which can measure between 0.6–3.5 m deep, and they reuse it in following nesting seasons (Masello & Quillfeldt 2005, Masello et al. 2006). Each cavity is occupied by a single pair that lays between 2–5 eggs in the nest chamber at the end of the tunnel (Masello & Quillfeldt 2002, 2004a, Vargas-Rodríguez & Squeo 2014). Female parrots incubate their eggs for an average of 24 days, with hatching occurring from late October to November (Masello & Quillfeldt 2002). Nestlings remain in the nest for approximately 60 days until they leave the nest in January (Masello & Quillfeldt 2002, Vargas-Rodríguez & Squeo 2014).

Colony size. In early October 2019, we estimated the size of the colony by direct counts of Burrowing Parrots present on the cliff. Counts were carried out between 09:00 and 10:30 h local time, as this is the time of day when there is the greatest influx of adult individuals to the colony from the foraging sites (Masello et al. 2006, Lera et al. 2023b). For this, we established a 1-km transect along the sandy beach in front of the cliff, at a distance of 50 m, considered to be the minimum distance so as not to disturb nesting parrots (Amione et al. 2024). The estimated colony size corresponded to the average of two simultaneous counts in the first week of October.

Reproductive Parameters. To obtain information on clutch and brood size, we randomly inspected 88 potential nest-cavities during the months of October to January in the 2019–2020 breeding season, and 90 potential nest-cavities from November to December in the 2021–2022 breeding season. At the start of each breeding season, we took a digital photograph of the entire cliff on which we marked cavities inspected by parrots as potential nest-sites. This enabled us to identify and locate nest-sites quickly and prevented unnecessary marking of the cliff. A cavity was considered a potential nest-site, and selected for inspection, if we saw adults entering and exiting the cavity. We also inspected cavities adjacent to potential nest-cavities.

In each breeding season, we inspected potential nest-cavities using an endoscopic camera of 5.5 mm diameter available for Android©(Endoscope). We gained access to the cavities using an extendable ladder of 7–15 m height, lent to us by local fire fighters. Each inspection took place early in the morning between 07:00 and 13:00 h local time. Earliest hatching is re-

ported as 25 October at the El Condor colony (Masello & Quillfeldt 2002), therefore we performed one or two inspections of a few cavities on the first days of October to determine the start of the incubation period. We observed eggs on 12 October 2019 and allowed at least a week to pass since the first eggs were observed to avoid nest abandonment (Masello & Quillfeldt 2012). We then made the first inspection of all 88 potential nest-cavities on 23 October 2019, corresponding to the incubation period. A potential nest-cavity was confirmed as a nest if adults, eggs or nestlings were observed inside the cavity. If no sign of activity was evident, we registered the cavity as "inactive", and it was not included in productivity estimates of nests. On 17 November 2019, we observed the first hatchlings, and allowed a few days to pass to avoid nest abandonment. We made the second inspection of the selected nests on 30 November and 10 December 2019, corresponding to the period after hatching documented for the colony of El Condor (Masello & Quillfeldt 2002). In a similar way, we set the dates for the third inspection of the nests on 29 December 2019 and 3 January 2020, prior to fledging (Masello & Quillfeldt 2002).

For the 2021–2022 breeding season, we followed the same monitoring methodology as for the 2019–2020 breeding season. However, we were unable to visit the colony in October 2021 due to a delay by the authorities in issuing the necessary permits. Therefore, first cavity inspections were conducted on 2 November 2021 for the incubation period, during which we also registered some hatchlings. Further inspections were conducted on 23 November 2012 to record hatchlings, and 26 and 27 December 2012 prior to fledging. Based on our observation during both breeding seasons, we estimate that for this colony, egg-laying occurs during the first half of October, and hatching during the first half of November.

We determined hatching success as the proportion of eggs that hatched. We estimated nestling survival as the proportion of hatchlings reaching 42 and 54 days of age for the 2019–2020 and 2021–2022 breeding seasons respectively. We also estimated nest success for both seasons separately, defined as the percent of nests that produced at least one fledgling. If, after recording eggs or hatchlings in a nest, we saw no evidence of activity in subsequent inspections, we recorded the nest as failed or abandoned. To assess differences in clutch size, number of hatchlings, and number of fledglings between the two breeding seasons, we performed a Mann-Whitney *U* test, using a significance level of $P \leq 0.05$.

RESULTS

We estimated a colony size of 960 Burrowing Parrots in October 2019. Of the 88 potential nest-cavities inspected during the 2019–2020 breeding season, 46 were confirmed to contain adults or eggs, 37 (42%) were inactive throughout the breeding season, and five nests became inaccessible for inspection. Of the 46 confirmed nests, 37 nests remained active during the entire breeding season, and nine nests (19.6%) failed due to abandonment or cliff collapses. Of the failed nests, five were abandoned during the incubation phase, three were abandoned during the hatchling phase, and one was lost due to cliff collapses after the second inspection.

We registered a total of at least 123 eggs in 46 nests during the 2019–2020 breeding season. We determined a mean clutch size of 3.2 ± 1.3 eggs per nest (range: 1–5 eggs, N = 18 nests), with a mode of 4 eggs (Figure 2). Hatching success was 81.3% for 123 eggs producing 100 hatchlings. Most of the nests inspected had 2 and 4 hatchlings (range: 1–5 hatchlings; Figure 2), with a mean productivity of 2.8 ± 1.2 hatchlings per nest (N = 27 nests). Nestling survival was 63.4%, where 78 hatchlings survived to 42 days of age in a total of 37 nests. Most nests had 2 potential fledglings (range: 1–5 fledglings; Figure 2), and we estimated a mean overall productivity of 1.7 ± 1.3 fledglings per nest (N = 46 nests). Of the 37 nests that had potential fledglings, five nests (13.5%) suffered hatching failure (loss of eggs) and 13 nests (35.1%) brood reduction (loss of hatchlings). The apparent nest success for this breeding season was 80.4%.

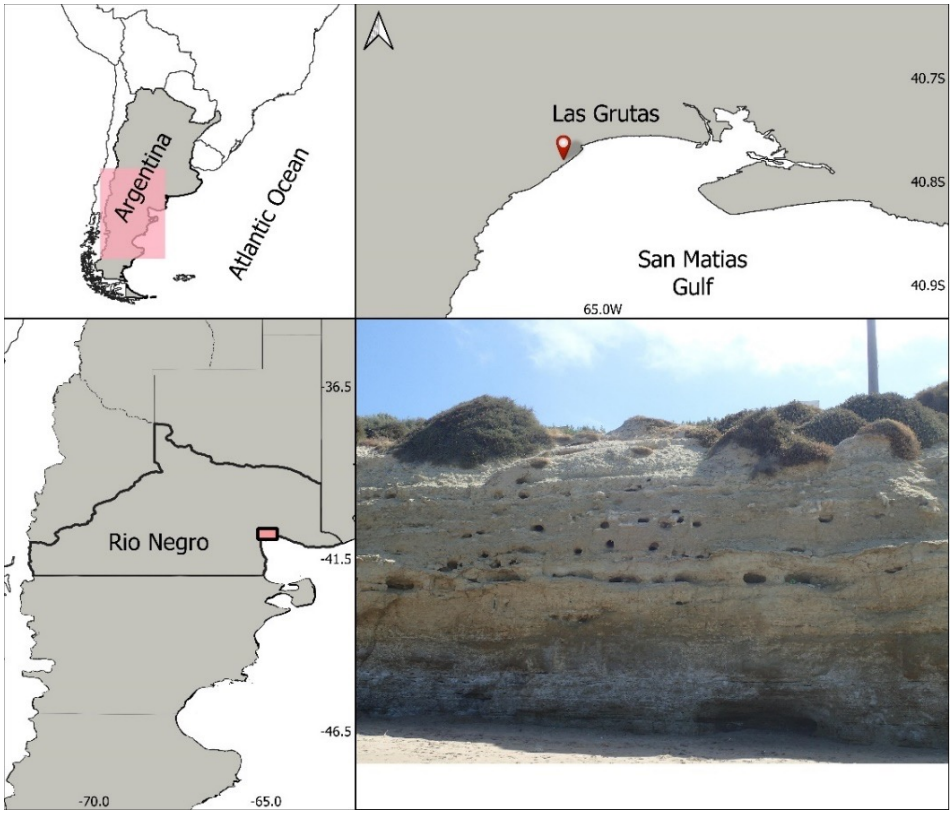

Figure 1. Study site Las Grutas, Río Negro, Argentina. White arrows indicate the nests of Burrowing Parrots.

Of the 90 potential nest-cavities inspected in the 2021–2022 breeding season, 82 were confirmed as nests, and eight were recorded as inactive (8.9%). Of confirmed nests, 42 were determined to be active throughout the breeding season, and 40 failed due to abandonment. Of the failed nests, 23 were abandoned after the first inspection, and 17 were abandoned between the hatching and fledging periods.

We registered a total of 234 eggs in 82 nests in the 2021–2022 breeding season. We estimated a mean clutch size of 2.8 ± 1.3 eggs per nest (range: 1–5 eggs, N = 46 nests) and a mode of 4 eggs (Figure 2). We estimated a hatching success of 64.1% for 234 eggs producing 151 hatchlings. We determined a mean of 1.6 ± 1.6 hatchlings per nest and the mode was of 3 hatchlings (N = 59 nests; Figure 2). During the second inspection, we also observed 17 nests that still had eggs and no hatchlings, and four nests with eggs and recent hatchlings. Nestling survival was 40.6% with 95 nestlings surviving to 54 days of age in 42 nests. Most nests had 2 potential fledglings (Figure 2), and we estimated a mean productivity of 1.2 ± 1.3 fledglings per nest (N = 82 nests). The apparent nest success for this breeding season was 51.2%. Of the 42 nests with potential fledglings, four nests (9.5%) suffered hatching failure and 12 nests (28.6%) brood reduction. Mann-Whitney *U* test for differences between breeding seasons in clutch sizes, hatchlings, and fledglings were not significant.

DISCUSSION

In terms of colony size, our census yielded a total of 960 Burrowing Parrots at Las Grutas. The most recent census of the sector was conducted in 2008, estimating a total of 420 active nests (Masello et al. 2011), which equates to 840 breeding adults. While our count resulted in a larger number of individuals, it is possible that immature individuals or floaters might be included in our counts. Indeed, the estimation conducted in El Cóndor revealed that nearly 8% of the colony was represented by non-breeding individuals (Masello et al. 2006). Therefore, if we apply this estimate of 8% non-breeding individuals to our results, we could estimate that the colony consists of 883 breeding adults. This suggests that the Burrowing Parrot colony of Las Grutas has maintained a stable breeding population over time.

Reproductive parameters of the population at Las Grutas did not differ between years and the values were within the range reported for other colonies. Clutch and brood sizes were lower than those reported for the species at El Cóndor (Masello & Quillfeldt 2002, 2004a), but similar to the Bahía Blanca colony (Lera et al. 2023a). Hatching success and nestling survival at Las Grutas were also below the values of 91% to 88% reported by Masello & Quillfeldt (2002, 2004a) for the El Cóndor colony in a normal precipitation year. However, the 63.4% nestling survival at Las Grutas in the 2019–2020 breeding season was similar to the 65% nestling survival observed by Masello & Quillfeldt (2004a) during a drier La Niña year at El Cóndor. Nevertheless, mean number of fledglings per nest at Las Grutas was lower than all estimates for El Condor by Masello & Quillfeldt (2002, 2004a). It should be noted that we counted fledglings at earlier nestling ages of 42 and 54 days, compared to nestlings older than 55 days considered by Masello & Quillfeldt (2002, 2004a). Thus, caution must be taken with our estimates of fledglings. However, fledglings per nest observed in our study were similar

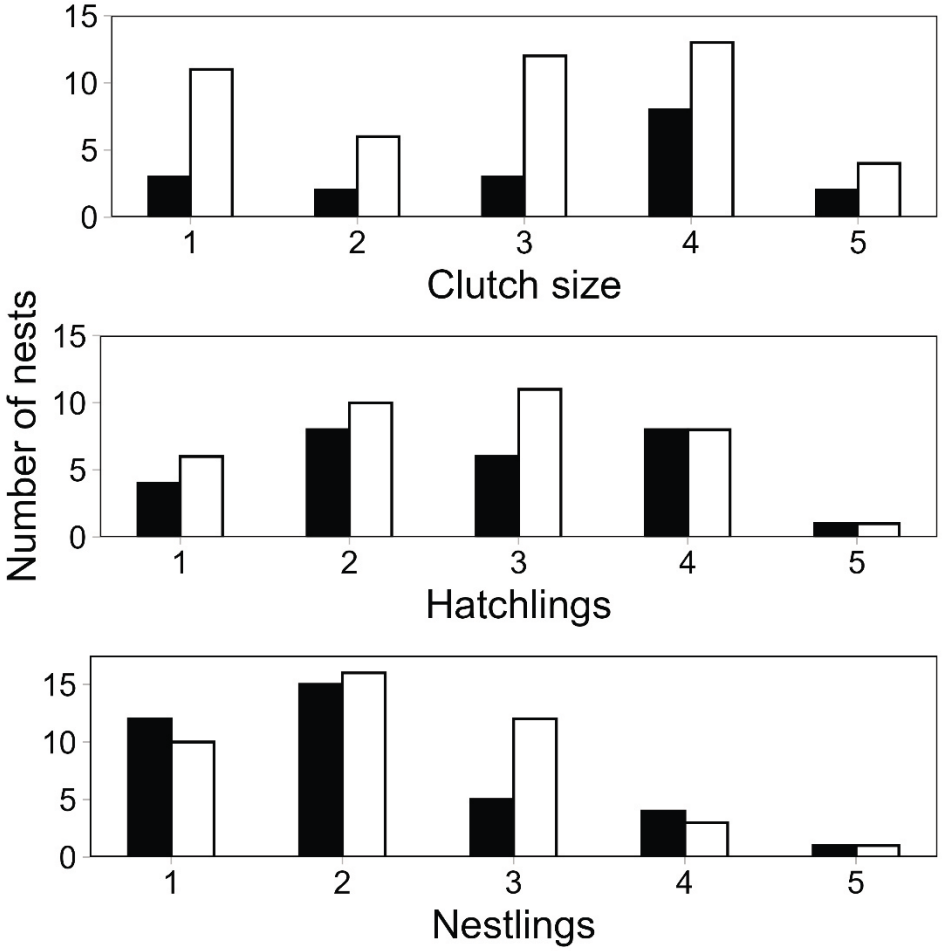

Figure 2. Estimated clutch sizes, and number of hatchlings and fledglings of the Burrowing Parrot for the 2019–2020 (black bars) and 2021–2022 (white bars) breeding seasons at the Las Grutas colony, Argentina.

to those estimated by Lera et al. (2023a) in urban colonies of the species.

We registered more nests as abandoned during the breeding season 2021–2022. We observed no other avian species making use of the cliff cavities for nesting apart from a few individuals of the Southern Martin *Progne elegans*, but other potential vertebrate predators were spotted within the study colony in the 2019–2020 breeding season, including a single domestic cat *Felis silvestris catus* walking among the Burrowing Parrot nests (Ludmila L. D. Amione pers. obs.). Furthermore, we observed a few pierced eggs in the 2019–2020 breeding season that could indicate a sign of predation. For certain species of *Amazona* sp., predation is a considerable cause of nest failure (Renton & Salinas-Melgoza 2004, Rivera et al. 2012, Berkunsky et al. 2012), although predation is not the main threat perceived for the Burrowing Parrot in El Cóndor (Failla et al. 2008, Masello & Quillfeldt 2012, Sánchez et al. 2016). Future studies of the colony at Las Grutas should evaluate predation risk and assess the impact on reproductive success of the Burrowing Parrot.

We also observed hatching failures and brood reductions in both breeding seasons at Las Grutas. Brood reduction has been reported for the Burrowing Parrot at the El Cóndor colony, with mortality of last hatched nestlings at around 20 days of age in a La Niña year (Masello & Quillfeldt 2002, 2004a). Climatic factors, such as severe droughts, can impact reproductive success of the species, particularly driving brood reductions (Masello & Quillfeldt 2004a, Renton & Salinas-Melgoza 2004).

Although we did not measure climatic variables in our study, variations in precipitation levels could have influenced the lower productivity we observed for the Burrowing Parrot in the 2021–2022 breeding season. According to the National Meteorological Service, during 2021 the precipitation levels estimated for the study area were lower in the months preceding the parrot breeding season, compared to the months preceding the 2019–2020 breeding season. These conditions could have affected food availability for the 2021–2022 breeding season with the consequence of a higher nest abandonment. Temperature and rainfall patterns can influence the reproductive variability of parrot species (Masello & Quillfeldt 2004a, Renton & Salinas-Melgoza 2004, Juárez et al. 2012). Droughts have a significant impact on food sources of granivorous and frugivorous avian species and can ultimately affect the fitness of these species (Sanz & Rodríguez Ferraro 2006, Ortiz-Maciel et al. 2014, Renton et al. 2015). If food resources are limited, it is expected that reproductive output would be lower (Díaz et al. 2012).

To conclude, the Burrowing Parrot colony of Las Grutas has remained stable over the 16 years since the last census conducted by Masello et al. (2011). Moreover, the reproductive parameters we estimated for the Burrowing Parrot were generally lower than those determined for the colony at El Cóndor, although similar to those obtained by Lera et al. (2023a) for a colony in an urbanized area of southern Buenos Aires Province. Our results serve as a baseline for future research on the Burrowing Parrot at the Las Grutas colony in the northern section of the San Matías Gulf.

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