

## Risk-taking behavior by a cavity-nesting parrot breeding at northern Patagonia, Argentina

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**ABSTRACT.** The increase in human population poses great challenges to birds inhabiting coastal areas, and studying their behavioral responses against these disturbances is an effective approach to understanding how tolerant species are. Our main goal was to describe the risk-taking behavior of breeding burrowing parrots (*Cyanoliseus patagonus*) against an approaching person. For this, we measured flight initiation distance (FID) and latency time of nesting burrowing parrots on a reproductive colony situated northwest of the San Matías Gulf, northern Argentine Patagonia. We also inquired how anthropic, environmental and ethological variables affected this behavior, and checked if the species' reproductive success of the species varied against such disturbance. The mean FID estimated and the mean latency time were only affected by cloud coverage, and both increased with overcast conditions. burrowing parrots did not modify their FID throughout the breeding season, but returned to previous activities sooner as the breeding season progressed. The effect of our experimental disturbance did not affect the reproductive success of the species. Our results suggest that burrowing parrots show a tameness to the disturbance caused by a human approach, as reflected by their relatively short flight initiation distances, an effect also reported in other bird species inhabiting urban habitats.

[Keywords: Psittaciformes, burrowing parrot, flight initiation distance, flush distance, behavior]

**RESUMEN. Comportamiento de riesgo de una especie de loro que nidifica en cavidades al norte de la Patagonia, Argentina.** El aumento de la población humana impone grandes desafíos a las aves silvestres que habitan zonas costeras. Estudiar las respuestas comportamentales de estos organismos ante tales disturbios resulta efectivo para comprender la tolerancia de las especies a las actividades de origen antrópico. Nuestro principal objetivo fue describir el comportamiento de riesgo de loros barranqueros (*Cyanoliseus patagonus*) reproductores hacia una persona aproximándose. Para ello, cuantificamos la distancia de iniciación de vuelo y el tiempo de latencia del loro barranquero en una colonia situada al noroeste del Golfo San Matías, al norte de la Patagonia Argentina. Además, evaluamos el efecto de variables ambientales, antrópicas y etológicas sobre el comportamiento, y evaluamos la variación del éxito reproductivo de la especie ante dicho disturbio. La distancia de iniciación de vuelo media y el tiempo de latencia medio fueron afectados principalmente por la cobertura de nubes, con una tendencia a incrementar durante condiciones más nubladas. Los individuos estudiados del loro barranquero no modificaron su distancia de iniciación de vuelo durante el ciclo reproductivo. Sin embargo, retomaron sus actividades más pronto a medida que el ciclo avanzaba. El efecto del disturbio experimental no afectó el éxito reproductivo de la especie. Nuestros resultados sugieren que el loro barranquero percibe como bajo riesgo al disturbio que genera la aproximación de una persona, viéndose esto reflejado en las distancias de iniciación de vuelo relativamente cortas, un efecto que también se observó en otras especies de aves que habitan zonas urbanas.

[Palabras clave: Psittaciformes, loro barranquero, distancia de iniciación de vuelo, distancia de escape, comportamiento]

## INTRODUCTION

Modern threats to biological diversity are primarily driven by human activities (Zhai et al. 2020; Prakash and Verma 2022). The current human population size is estimated at 8000 million people, imposing an enormous pressure on natural populations (Cafaro et al. 2022). While most of the human-wildlife conflict takes place in large cities, small and remote touristic locations are often exposed to massive short-term pulses of incoming visitors, with a potential negative effect on wildlife. Marine coastal areas are an example of such modern localized short-term pulses of human visitors, with a marked high season during the summer months (Gormsen 1997; Burak et al. 2004). In addition, such areas also encompass breeding, feeding and refueling grounds for a diverse array of vertebrates, particularly birds. These organisms enable the development of models for inquiring about the adaptation of vertebrates to human activities (Levey et al. 2009; Lowry et al. 2013).

The reported effects of human disturbance on birds are diverse and include changes in demography (Bolduc and Guillemette 2003), distribution (Bötsch et al. 2017), physiology (Ellenberg et al. 2013; Tarjuelo et al. 2015) and behavior (Beale and Monaghan 2004). Knowledge of animal behavior has proven to be a useful tool for addressing conservation solutions to wildlife threats (Sutherland 1998; Berger-Tal et al. 2011). Among animal behavior, risk-taking behavior has been broadly addressed for understanding the tolerance of a species against a perceived threat (Frid and Dill 2002).

The most widespread form of studying risk-taking behavior is measuring the distance at which birds notice the presence of a potential threat (i.e., alert distance) (Fernández-Juricic et al. 2001a) and, ultimately, flee (i.e., flight initiation distance) (Blumstein 2003). The available literature suggests that the prey response is inversely proportional to the distance between the animal and the stimulus (Weston et al. 2012). In the presence of a potential threat, the prey's optimal flight initiation distance will be a function of a trade-off between remaining in its position or taking off. If the energetic cost of staying in its position overcomes those for fleeing, the prey will flush (Ydenberg and Dill 1986; Blumstein 2010). Latency time is also considered a measure of the perceived risk and is defined as the period it takes for an individual to resume pre-

disturbance activities; the greater the latency time, the more significant the perceived risk (Fernández-Juricic et al. 2004).

During the breeding season, changes in adult survival and current reproductive value are expected to drive antipredator behavior of a species (Mallory et al. 1998; Dowling and Bonier 2018). According to parental investment theory, the risk taken by nesting birds increases with current reproductive value (i.e., as the brood progresses), meaning that the optimal strategy taken by an adult facing this situation is to remain at the nest (Dowling and Bonier 2018). During the nesting season, when adults are faced with a higher risk of predation, they will consider their own survival, nestlings' survival and future reproductive success (Quillfeldt et al. 2005). Furthermore, responses to a threat differ between species and within certain species, as individuals are more capable of coping with more challenging situations, such as those imposed by urbanized sites. In this sense, shy behavior (e.g., longer flight initiation distances) was reported from birds inhabiting rural environments (i.e., habitats with low disturbance), in contrast with their conspecifics occupying urbanized areas like cities, where they show less risk-aversion behavior (Lowry et al. 2013; Ducatez et al. 2017).

Among birds, Psittaciformes encompass many species, several of which face different levels of threats mainly related to human activities (Olah et al. 2016). Parrot behavior has been widely studied in captivity (Wilkinson 2000; Wilson and Luescher 2006), which may be related to the attractiveness of parrots to people or to the ease of capturing them in the wild, among other factors. However, the opposite is true for behavioral studies of wild populations (Berkunsky et al. 2017). Human intrusions and disturbances, such as recreational activities, are affecting more than 100 parrot populations in the Neotropics, and monitoring these populations has become a high priority activity (Berkunsky et al. 2017). Understanding tolerance through the study of risk-taking behavior of species inhabiting areas where human activities overlap with those of wildlife can be helpful for delineating buffer zones to minimize potential human disturbance on wildlife (Rodgers and Smith 1997).

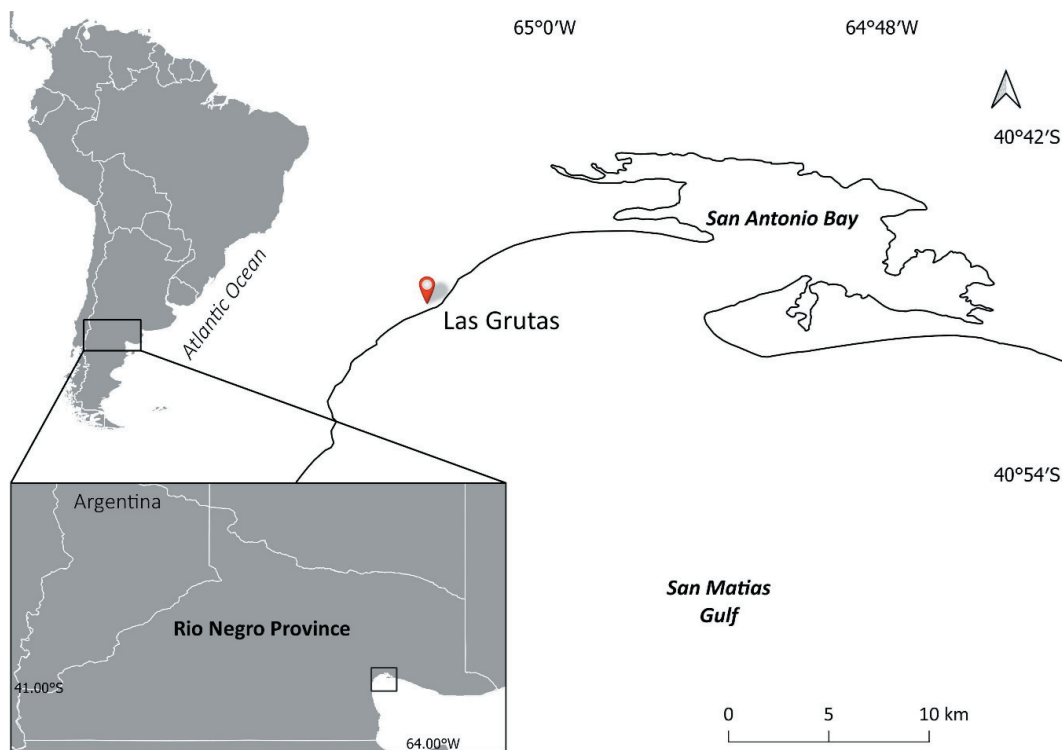
Through this work, we attempt to provide information on the tolerance of the breeding

burrowing parrot *Cyanoliseus patagonus* in the context of high levels of human disturbance throughout the breeding season. For this, we followed two objectives: a) to evaluate the risk-taking behavior of breeding burrowing parrots and b) to assess whether human recreational activities influence the reproductive parameters of the species. We hypothesize that since the burrowing parrot can perceive recreational users as potential disturbance 1) burrowing parrots will show a more active risk-taking behavior against recreational activities —with the associated predictions: a) longer flight initiation distance and latency time of burrowing parrots with increasing number of beach users, and b) lower parameters of reproductive success of burrowing parrots breeding in an area under experimental approaches—, and 2) due to an increasing parental care, burrowing parrots will decrease their risk-taking behavior along the breeding season —with the associated prediction a) shorter flight initiation distance and latency time in advanced stages of the breeding season—.

## MATERIALS AND METHODS

### Study site

We conducted the study at Las Grutas, Río Negro province, Argentine Patagonia (Figure 1), where burrowing parrots have their third most extensive breeding colony in the province with 420 active nests (Masello et al. 2011). This site is characterized by sandstone cliffs extending ~5 km along the coast, with varying heights between 6 and 12 m. Calcareous, coquinoïdal and clayey sandstones can be recognized on this cliff, in addition to pyroclastic material and abundant gypsum layers (Roque Kokot and Favier-Dubois 2017). This location belongs to the Monte phytogeographic region, in which species of *Larrea* sp., *Prosopis alpataco* and *Monttea aphylla* prevail (Cabrera 1971). This coastal area is particularly affected by the arrival of tourists to the city. The town of Las Grutas receives a considerable large number of visitors during the (austral) summer season (>300000 tourists arrived during the period 2021-2022) (unpublished data from



**Figure 1.** Geographic location of the studied burrowing parrot colony at Las Grutas in relation to Río Negro province, Argentine Patagonia.

**Figura 1.** Localización geográfica de la colonia de loro barranquero en Las Grutas con relación a la provincia de Río Negro, Patagonia Argentina.

the Tourism Secretary of Río Negro province) primarily for recreational and leisure activities. Such activities occur next to the colony of burrowing parrots, which overlap temporarily and spatially with the breeding season.

Adult burrowing parrots excavate their nests and burrow into the cliff at this study site and elsewhere along the species' breeding distribution. Though nesting pairs are known for re-using burrows excavated in previous seasons, they tend to enlarge them every year (Masello et al. 2002). Each burrow is occupied by a single pair that lays their eggs at the end of the tunnel known as nest chamber (Masello et al. 2002). Our study comprised one kilometer of this cliff. We selected this section because it corresponds to the densest sector of burrowing parrots nests (authors, personal observation).

The coasts of Las Grutas have belonged to the San Antonio Bay Natural Protected Area System since 1993. This protected area system encompasses a zonification based on allowed uses, from no-take zones to multiple-use areas (Management Plan Natural Protected Area San Antonio Bay 2012). We carried out our study in a multiple use zone, where human-wildlife encounters are expected, particularly with burrowing parrots.

#### *Data collection*

Data was gathered from September 2019 to January 2020 corresponding with the breeding season of the burrowing parrot (Masello and Quillfeldt 2012). We conducted most of the observations between 06:00 and 17:00 h local time (-3 GMT). The population size of the colony was estimated at the beginning of the breeding season between 9:44 and 10:12 h local time, considering daily movements of breeding adults (Masello et al. 2006). We estimated the colony population size by counting individual adults located at the entrance of their burrows on the cliff, along a 1 km long walking. Counts were tallied by two authors. The population size corresponds to the average of both counts.

#### *Behavioral measurements*

To evaluate how a possible human disturbance affects the behavior of nesting burrowing parrots, we conducted experimental approaches to estimate flight initiation distances and alert distances (FID and AD, respectively). We collected the data

working in pairs; one researcher approached a single focal bird at a steady pace (one step/s), linear and continuously with no obstacles preventing the focal bird and the observer from seeing each other (Fernández-Juricic et al. 2004). The researcher dropped one stake at the alert behavior (AD) and another when the bird flew (FID). The second observer measured the distances from the starting point to the lowered stakes (i.e., AD and FID), assisted with a laser rangefinder (Nikon Laser Forestry Pro 6x21, 6.0°, 10-500 m). We did not mark focal individuals; instead, we recorded responses to our approaches from randomly selected individuals. Flight initiation distance from unmarked individuals of the same population has been proved to be a reliable methodology in past studies (e.g., Madsen et al. 2009; Glover et al. 2011). We selected focal adults based on two characteristics: the adult was located at the entrance of its nest on the cliff and did not show alert behavior toward the observer before the approaching process began. We assumed that any individual at the entrance of a nest was a breeding adult. To avoid the differential reaction to the researchers, we used the same colored clothes during the experiments. We measured the distance to the entrance of the nest (Euclidean distance) at the beginning of the experimental approach, and afterwards FID and AD were calculated using trigonometry (Fernández-Juricic et al. 2004); FID could equal AD but could never be longer. We recorded starting distance (i.e., the distance between the focal bird and the approaching disturbance when the approach started; SD hereon) to control for its potential confounding effects (Blumstein 2003). In a pilot study, we determined that an observer could estimate the alert behaviors of burrowing parrots from a distance at least 50 m apart. We conducted the 2018 pilot study during the breeding season in the same area that was used later to collect data. For this, a comparison of different SD was used to identify the distance at which birds do not show no reaction toward us. The SD through the study period ranged from 50 to 83 m. Concomitantly, we recorded latency time for focal birds once they flee for a total duration of five minutes. Pre-disturbance activity of the focal bird was determined a priori as well as the responses to the experimental approach. The former included: copulation (Cplt), nest cleaning (Nst), resting (Rstn), scanning (Scnn), self-grooming (Slf), vocalization (Vclz) and agonistic behavior (ABh); the latter included: remaining in place (Remn), bird hikes within or beyond

the sight of the approaching observer (HkWs or HkBS, respectively), bird flies within or beyond the sight of the approaching observer (FIWs or FIBs, respectively), bird reacts to the approaching observer by entering its own nest or other's nest (ENst) and bird flies toward the approaching observer (FITwrd). To avoid conditioned responses by the parrots during the experiments, two cautions were considered: observations varied at least one day between them, and a minimum of 100 m were kept between subsequent focal birds.

#### *Environmental, anthropogenic and ethological variables*

Along with our experimental approach, we gathered data from a suite of variables that could potentially affecting risk-taking behavior of birds. As environmental variables, wind direction (east, north, west, south), wind intensity (km/h) and cloud cover (clear, partly cloudy, overcast) relative to the observer were measured. Anthropogenic variables included number of beach users, number of aquatic activities (i.e., swimmers, motorboats and non-motorized boats), number of dogs, number of motorized and non-motorized vehicles and ambient noise measured in decibels (dB) using a sound level meter application available for Android. This application registered the minimum and maximum value for ambient noise. We calculated their mean values to use in the analysis. These anthropogenic variables were measured in a 50x50 m plot around the focal individual. Concerning ethological variables, we divided the breeding season into four stages as follows: egg pre laying (i.e., a stage in which courtship, choice of partner, copulate, nest conditioning predominates; hereinafter considered as EPL), incubation (i.e., more than a half of the colony has laid eggs; regarded as IN), chick guarding (i.e., chicks younger than 15 days since hatching; hereinafter treated as NE) and chick fledgling (i.e., chicks older than 40 days since hatching; regarded as FL). We also registered the number of conspecifics in relation to the focal bird in a 10-m radius circular plot before the approach began.

#### *Reproductive parameters*

To evaluate potential effects of human disturbance over reproductive parameters of burrowing parrots, we divided the study site into two similar areas that received different levels of disturbance as follows:

one area where the experimental approach was performed (hereinafter considered as experimental area) and another area where no experimental disturbance was applied (hereinafter treated as control area). We visited the colony at least twice: one or two visits to determine the beginning of a certain stage (i.e., IN, NE and FL) and another visit to record the number of eggs, nestlings and fledglings. We took the precaution of allowing a week to pass since the beginning of incubation and nestling periods until starting the monitoring of the nests to avoid abandonment (Masello and Quillfeldt 2012). Given that nesting pairs use the same burrow they have excavated in previous seasons (Masello and Quillfeldt 2002), we assume that the distribution of nests along the cliff keeps relatively constant through one breeding season. Thus, digital photographs of the cliff at the beginning of the breeding season were obtained to individualize each nest for further monitoring. The nests were chosen at random during the samplings. We monitored a total of 90 nests (45 nests for each experimental and control area) using an endoscope camera available for Android, and the number of eggs and fledglings was recorded from both the digital images obtained and by direct observation of the nests. We define hatching success as the proportion of eggs that hatched (and survived at least one week since hatching) over the total number of eggs. For fledging success, we based on data from chicks surviving to 42 days of age, corresponding to the age when chicks are highly mobile but not yet capable of flying, and define it as chicks fledged over total chicks hatched (Masello and Quillfeldt 2002). A subsample of 16 nests — 8 in the control area and 8 in the experimental area — with complete information on the number of eggs and chicks was used for the subsequent analysis.

#### *Statistical analyses*

All response variables (i.e., AD, FID) and latency time failed to pass the homoscedasticity and normality tests. We found a correlation between AD and FID (Spearman correlation,  $r=0.51$ ,  $P<0.00$ ,  $n=116$ ), situation previously suggested by other studies (Fernández-Juricic et al. 2001b; Blumstein 2003). Hence, we excluded AD as covariate in all models. We performed a correlation matrix to test the possible collinearity between explanatory variables and thus remove those showing a significant correlation from further analysis. For this, we use the *corrplot* function from

the corrplot package v0.92 (Wei and Simko 2021) (Figure 2). We searched for differences in median FID and latency time between stages of the breeding season by running a Kruskal-Wallis test (Kruskal and Wallis 1952). For significant differences, we performed a Dunn test of multiple comparisons with a Bonferroni correction (Dunn 1961, 1964) using the dunnTest function from the FSA package v0.9.1 (Ogle 2016).

We used generalized linear models (GLM) to determine how the response variables (i.e., FID and latency time) varied as a function of environmental, anthropogenic and ethological predictors. We modeled FID using a Gamma error distribution family with a log link function and a negative binomial error distribution family with a log link function for latency time. We constructed models with starting distance, number of coastal users, number of conspecifics, wind direction (factorial, with four levels: east, north, west, south), mean ambient noise and cloud coverage (factorial, with three levels: clear, partly cloudy and overcast) as explanatory variables. Explanatory variables such as wind intensity, aquatic activities, number of dogs

and presence of vehicles were excluded from all modelling analysis due to the presence of correlation (see supplementary material). For modeling FID and latency time, we used glm and glm.nb functions in the R package stats and MASS v7.3-54 (Venables and Ripley 2002), respectively. All analyzes were performed with R version 4.1.0 (R Core Team 2021). To test for differences in reproductive parameters (i.e., hatching success and reproductive success) between the control and experimental areas, we applied a Mann-Whitney test.

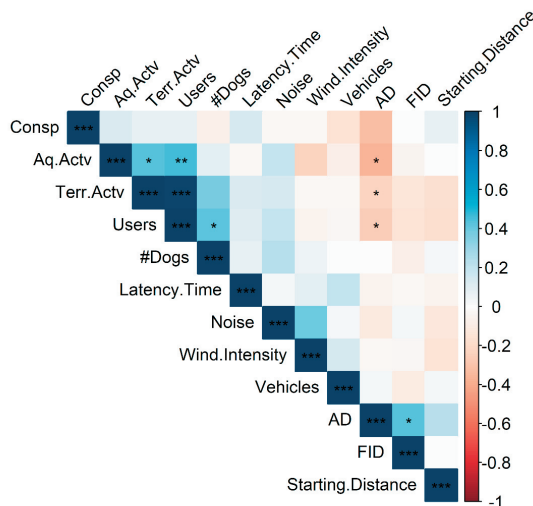
We calculated a buffer area and a minimum approach distance to adult burrowing parrots following methods described in Fox and Madsen (1997). The latter was estimated to be three times the mean FID. The buffer area was estimated as  $\pi * (1.5 * FIDm)^2$ , where FIDm is the mean FID. The estimated area was considered to have a circular shape. The means are presented with two standard errors. In all cases, the tests were considered significant at  $P < 0.05$ .

## RESULTS

### Behavioral measurements

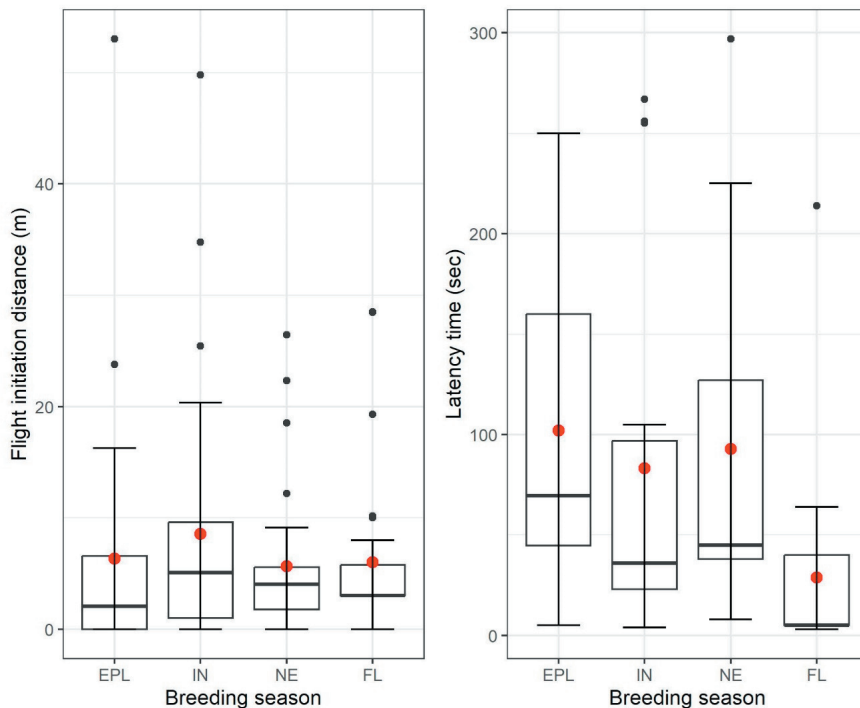
We gathered a total of 116 direct approaches to burrowing parrots throughout the species breeding season (n=30 for each stage, except for EPL where n=26). The flight initiation distance ranged from 0 to 53 m and the mean FID for the whole period was estimated at  $6.6 \pm 0.85$  m. Mean distance at EPL stage was estimated at  $6.61 \pm 2.15$  m, at IN was  $8.58 \pm 2.08$  m, and at NE and FL were  $5.43 \pm 1.22$  m and  $6.02 \pm 1.30$  m, respectively. We did not find significant differences in FID between stages of the species' breeding season (Kruskal Wallis  $\chi^2_{3,116} = 1.61, P = 0.45$ ) (Figure 3). Therefore, the FID data was pooled for subsequent analysis.

Throughout the breeding season, ~47% of focal birds were observed resting before the experimental approach began, and 25% were scanning. Other behaviors such as 'copulation' were only observed during the first stage (i.e., egg pre-laying EPL) as depicted in Figure 4. Considering the entire breeding season, ~45% of the individuals flushed within the sight of the observer when experimentally approached. This response was followed by 'Remain' behavior (~40%). Except during the egg pre-laying stage, these proportions were kept constant for all stages (Figure 5).



**Figure 2.** Matrix correlation between anthropic and environmental variables, FID (flight initiation distance) AD (alert distance), and SD (starting distance). Aq.Actv: aquatic activities. Terr.Actv: terrestrial activities. Users: number of beach users. #Dogs: number of dogs. Noise: ambient noise measured in decibels. \*: 0.1; \*\*: 0.01; \*\*\*: 0.001.

**Figura 2.** Matriz de correlación entre variables antrópicas, ambientales, FID (distancia de iniciación de vuelo), AD (distancia de alerta) y SD (distancia inicial). Aq.Actv: actividades acuáticas. Terr.Actv: actividades terrestres. Users: número de usuarios costeros. #Dogs: número de perros. Noise: ruido ambiental medido en decibeles. \*: 0.1; \*\*: 0.01; \*\*\*: 0.001.



**Figure 3.** Box plot representing the FID on the left and the latency time on the right of the focal burrowing parrot nesting in Las Grutas through stages of the species breeding season. Box: the lower and upper hinges represent the first and third quartiles; the line inside the box represents the median, and the red dots, the mean. The upper whisker extends from the hinge to the largest value no further than  $1.5 \times \text{IQR}$  from the hinge. The lower whisker extends from the hinge to the smallest value at most  $1.5 \times \text{IQR}$  of the hinge. Data beyond the end of the whiskers are outliers. EPL: egg pre laying. IN: Incubation. NE: Nestlings. FL: Fledglings.

**Figura 3.** Gráfico de cajas con bigotes representando la distancia de iniciación de vuelo (FID) a la izquierda y el tiempo de latencia a la derecha de individuos focales del loro barranquero nidificando en Las Grutas, dividido por períodos del ciclo reproductivo de la especie. Caja: los extremos inferior y superior de la caja representan el primer y tercer cuartil, la línea horizontal dentro de la caja representa la mediana, y los puntos rojos, la media. El bigote superior se extiende desde el tercer cuartil hasta el valor más grande no más allá de  $1.5 \times \text{RIC}$  desde el cuartil. El bigote inferior se extiende desde el primer cuartil hasta el menor valor no más allá de  $2 \times \text{DS}$  desde el cuartil. Los puntos fuera de los bigotes son valores atípicos. EPL: pre-puesta. IN: incubación. NE: pichones tempranos. FL: pichones maduros.

Regarding FID, the global model showed a good fit to the data with a slight sub-dispersion ( $\hat{c}=0.92$ ) accounting for 17.53% of the explained deviance. The modelling performed showed a significant effect of cloud coverage on the focal birds' mean FID (Table 1); the mean FID was significantly longer during partly cloudy and overcast conditions.

Latency time was significantly different between stages of the breeding season (Kruskall Wallis  $\chi^2_{3,64}=13.16$ ,  $P=0.00$ ) (Figure 3). Post-hoc comparisons showed a significant difference between egg pre-laying and fledgling stages (Dunn test  $Z_{\text{EPL-FL}}=3.51$ ,  $P_{\text{adjusted}}=0.00$ ). The mean latency time for the entire breeding season was calculated at  $72.28 \pm 10.49$  s ( $n=64$ ). Considering the stage of the breeding season, this metric varied from  $101.88 \pm 19.37$  s during EPL ( $n=18$ ),  $83.28 \pm 26.48$  s during IN ( $n=14$ ),  $92.72 \pm 29.41$  s during NE ( $n=11$ ), to  $28.85 \pm 0.37$  s during FL ( $n=21$ ). We were able to measure the latency

time for 101 (87%) focal birds approaching (i.e., individuals that remained within the sight of observers). Of these, 64 focal birds took less than five minutes to resume previous activity (72.2 s), whereas the remaining individuals took longer and hence we stopped recording (see Behavioral measurements). The dispersion parameter of the model showed a slight overdispersion ( $\hat{c}=1.31$ ), accounting for 27.86% of the explained deviation. The modeling showed that the mean latency time was significantly longer during partly cloudy and overcast conditions (Table 2). In this study, the minimum linear approach distance and buffer area were estimated at 23.59 m and 437.18 m<sup>2</sup>, respectively.

#### *Size and reproductive parameters of the colony*

We estimated a population size of 949 burrowing parrots along 1 km of coast throughout the 2019-2020 breeding season at

**Table 1.** Coefficients ( $\pm$ SE) from GLM describing the relationship between FID of burrowing parrots nesting in Las Grutas and the explanatory variables included in the model (n=116). The levels 'East' and 'clear' from the explanatory factorial variables Wind Direction and Cloud Coverage, respectively, were used as the reference category in the model.

**Tabla 1.** Coeficientes ( $\pm$ SE) del modelo lineal generalizado que describen la relación entre la distancia de iniciación de vuelo (DIV) de loros barranqueros nidificando en Las Grutas y las variables explicativas incluidas en el modelo (n=116). Los niveles 'East' y 'clear' de las variables explicativas Wind Direction y Cloud Coverage, respectivamente, se utilizaron como categorías de referencia en el modelo.

	Factor levels	Estimate	SE	t	P
Intercept		3.12	1.03	3.03	<0.01
Number of coastal users		-0.01	0.00	-1.84	0.06
Number of conspecifics		-0.00	0.01	-0.58	0.56
Noise level		-0.00	0.01	-0.55	0.58
Wind direction	North	-0.11	0.38	-0.30	0.76
	West	-0.56	0.48	-1.16	0.24
	South	0.07	0.41	0.18	0.85
Cloud cover	Partly cloudy	0.82	0.27	3.01	<0.01
	Overcast	0.75	0.30	2.42	0.01
Starting distance		-0.01	0.01	-1.46	0.14

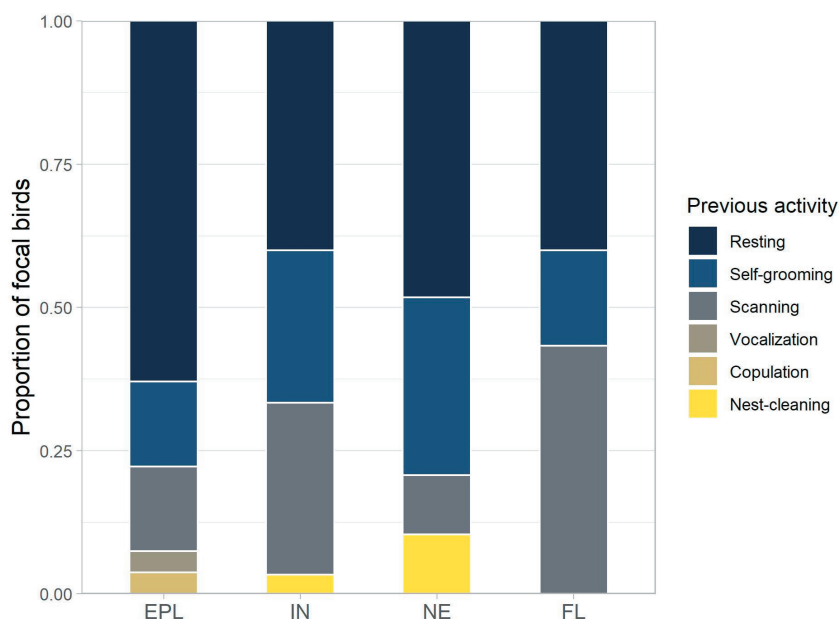


Figure 4. Focal Burrowing Parrots behaviours (ntotal=116) prior to experimental approach conducted in Las Grutas split by stages of the species' breeding season. EPL: Egg pre laying, IN: incubation, NE: nestling, FL: fledgling.

Figura 4. Comportamientos previos al disturbio experimental realizado en Las Grutas de individuos focales de Loro Barranquero (ntotal=116) dividido por periodo del ciclo reproductivo de la especie. EPL: Pre-puesta, IN: incubación, NE: pichones, FL: volantes.

**Table 2.** Coefficients ( $\pm$ SE) from GLM describing the relationship between latency time of burrowing parrots nesting in Las Grutas and explanatory variables included in the model (n=64). The levels 'East' and 'clear' from the explanatory factorial variables Wind Direction and Cloud Coverage, respectively, were used as the reference category in the model.

**Tabla 2.** Coeficientes ( $\pm$ SE) del modelo lineal generalizado (MLG) que describen la relación entre el tiempo de latencia de loros barranqueros nidificando en Las Grutas y las variables explicativas incluidas en el modelo (n=64). Los niveles 'East' y 'clear' de las variables explicativas Wind Direction y Cloud Coverage, respectivamente, se utilizaron como categorías de referencia en el modelo.

	Factor levels	Estimate	SE	z	P
Intercept		3.30	1.45	2.27	0.02
Number of coastal users		0.00	0.00	0.29	0.76
Number of conspecifics		0.02	0.01	1.87	0.06
Noise level		-0.00	0.01	-0.44	0.65
Wind direction	North	0.43	0.52	0.84	0.39
	West	0.17	0.63	0.27	0.78
	South	0.40	0.52	0.77	0.43
Cloud cover	Partly cloudy	1.53	0.37	4.06	<0.01
	Overcast	1.97	0.41	4.75	<0.01
Starting distance		-0.01	0.01	-0.86	0.38



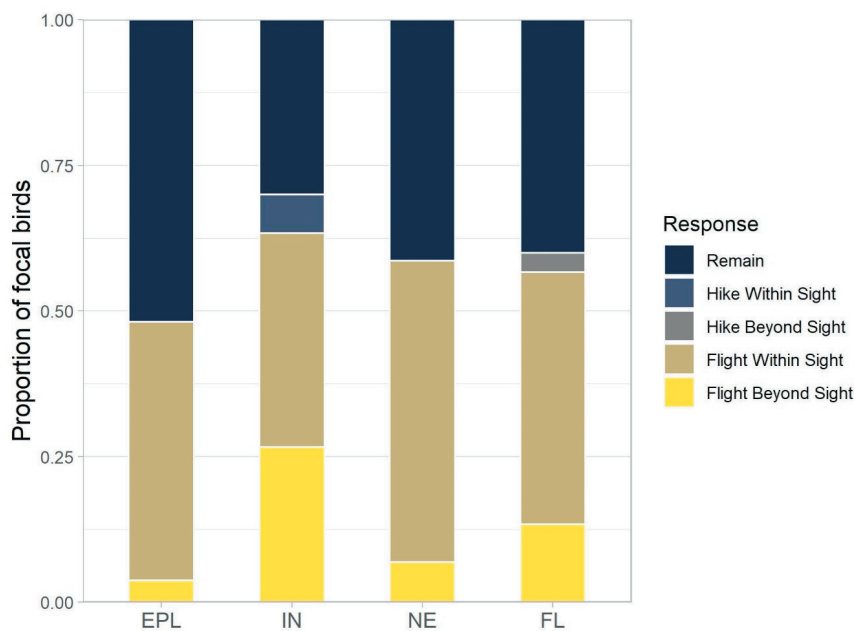


Figure 5. Focal Burrowing Parrots responses (ntotal=116) to experimental human approach conducted in Las Grutas split by the species' breeding season. EPL: Egg pre laying, IN: incubation, NE: nestling, FL: fledgling.

Figura 5. Respuestas comportamentales al disturbio experimental realizado en Las Grutas de individuos focales de Loro Barranquero (ntotal=116) dividido por periodo del ciclo reproductivo. EPL: Pre-puesta, IN: incubación, NE: pichones, FL: volantes.

**Table 3.** Mean values ( $\pm$ SE) of burrowing parrots reproductive parameters for the 2019-2020 breeding season at Las Grutas, compared between the experimental and control areas.

**Tabla 3.** Valores medios ( $\pm$ SE) de parámetros reproductivos del loro barranquero estimados en el área control y el área experimental durante la temporada reproductiva 2019-2020 en Las Grutas.

	Control area	Experimental area	W	df	P
Hatching success	0.85 $\pm$ 0.65	0.86 $\pm$ 0.09	33	1	0.94
Fledging success	0.93 $\pm$ 0.05	0.92 $\pm$ 0.05	27.5	1	0.63

Las Grutas. A total of 222 individuals were counted in the experimental area, while the remaining birds (n=727) were counted in the control area. No significant differences were found in the hatching success nor in the fledging success between these parameters based on a total of 16 nests (Table 3).

## DISCUSSION

Our main goal was to describe how breeding burrowing parrots behave towards a disturbance similar in magnitude to those imposed by beach users, both in terms of behavioral traits as well as in its reproductive parameters. There are limited research studying risk-taking behavior in birds such as parrots inhabiting Argentina (Spindler Díaz 2021). However, regional comparisons are possible since previous studies reported FID values for other parrot species from Australia (Weston et al. 2012) and elsewhere in the world, as we illustrate in Table 4. Since the pressure exerted by coastal users in Las

Grutas is presumably high during the summer season, along with the fact that the species colony placed there dates back to at least 2008 (Masello et al. 2011), we expected FID in breeding burrowing parrots to be relatively low. Table 4 shows that the estimated mean FID value falls within the known range of mean FID from related parrot species (Weston et al. 2012).

In this study, burrowing parrots do not modify FID while breeding, contrary to what we expected. However, we observed that during the last stage of the breeding season, burrowing parrots reduced their latency time to return more quickly to previous activities. Other studies have examined the effect of different stages of the breeding season on the risk behavior of birds, with varying results ranging from the detection of decreasing levels of defense on adult's killdeer *Charadrius vociferous* in later stages of the breeding season (Brunton 1990) to no effect (Lord et al. 2001; Glover et al. 2011). The available literature suggests that disturbance from recreation

**Table 4.** Mean flight initiation distances in meters (FID) of related parrot species from the southern hemisphere. n: number of FID measured. Sources: 1=Blumstein [2006]); 2=Blumstein in Weston et al. (2012); 3=this work.

**Tabla 4.** Distancias de iniciación de vuelo (DIV) promedio de especies emparentadas de loros del hemisferio sur. n: número de DIV medidas. Fuentes: 1=Blumstein (2006); 2=Blumstein en Weston et al. (2012); 3=este trabajo.

Species	Mean FID(n)	Country	Source
<i>Cacatua galerita</i>	15.3(41)	Eastern Australia and Tasmania	1
<i>Cacatua roseicapilla</i>	8.9(64)	Eastern Australia and Tasmania	1
<i>Callocephalon fimbriatum</i>	7.5(2)	Australia	2
<i>Calyptorhynchus banksii</i>	10.9(3)	Australia	2
<i>Calyptorhynchus funereus</i>	11.7(4)	Australia	2
<i>Cacatua sanguinea</i>	20(8)	Australia	2
<i>Cacatua tenuirostris</i>	3.8(1)	Australia	2
<i>Trichoglossus haematodus</i>	10(11)	Australia	1
<i>Trichoglossus chlorolepidotus</i>	1(1)	Australia	2
<i>Alisterus scapularis</i>	8.7(9)	Australia	2
<i>Aprosmictus erythropterus</i>	32.3(5)	Australia	2
<i>Platycercus elegans</i>	9.1(83)	Australia	1
<i>Platycercus eximius</i>	13.9(31)	Australia	1
<i>Platycercus adscitus</i>	21(3)	Australia	2
<i>Barnardius zonarius</i>	14.1(3)	Australia	2
<i>Psephotus haematonotus</i>	11.2(9)	Australia	2
<i>Cyanoliseus patagonus</i>	6.6(116)	Argentina	3

activities may have at least contemporary effects on the behavior and movement of birds within a habitat or localized area (Burger 1981; Buckley 2004). Moreover, some birds may habituate to different types of recreation disturbance and either not be disturbed or immediately return after the initial disturbance (Madsen 1995; Villanueva et al. 2014). This can be particularly true where human presence is frequent and non-threatening like activities related to recreation and leisure, enabling animals to lose their fear of humans and respond with shorter FIDs (Stankowich and Blumstein 2005; Samia et al. 2017). Furthermore, previous studies proposed that the most predictive factor explaining tolerance against human activities is the number of generations a species has been present on urbanized sites (Møller 2008). This may be the case of the burrowing parrot colony settled in Las Grutas, as it dates back at least over a decade ago (Masello et al. 2011). Furthermore, Tella et al. (2014) have described a breeding urban colony of burrowing parrot in southern Buenos Aires province, suggesting that this species was successful in colonizing urbanized sites and hence, might have learned within what distance a human can approach before representing a threat as seen in other studies (Carrete and Tella 2011). Nevertheless, no study shows the absence of response in environments heavily used by people (Schlacher et al. 2013), and ours is not an exception since all individuals disturbed in our study, even if they did not escape by

flight, showed an alert behavior towards the approach. This suggests that if a habituation process occurs, it would be limited on the temporal scale (Schlacher et al. 2013; Watson et al. 2014). Finally, the variation in response to a disturbance depends on behavioral flexibility and phenotypic plasticity (Ghalambor and Carroll 2010; Blumstein 2014) and also on interindividual variability in behavioral traits (e.g., FID) that allow some species and even certain individuals of the same species to be more tolerant to human disturbances (Carrete and Tella 2011). Burrowing parrots nesting in Las Grutas probably do not perceive more significant predation risks from recreational activities exerted by beach users. Hence, they return quicker to their activities or do not flee at all.

According to our results, breeding burrowing parrots does not modify their risk-taking behavior under experimental approaches, as this behavior affected only by environmental variables. The analysis of environmental, anthropogenic and ethological variability affecting FID and the latency time of breeding burrowing parrots predicted a significant increase in both response variables with cloud coverage only. This could be related to the variation in birds' visibility under overcast conditions as light conditions are known for affecting certain behaviors of birds like orientation and navigation (Elkins 2004), and also the response to human disturbance (Webb and Blumstein 2005).

While we expected to find effects of anthropogenic activities on the parrots' response, the results obtained may indicate two things. One is that the parrots might perceive low risk due to the factors mentioned earlier. The other is that more evidence is needed to support our predictions. Concerning the latter, we have covered a wide range of time frames to conduct the experiments and observations. However, we are aware that during the peak influx of people to the beach, conducting experiments becomes challenging. On the one hand, the clustering of people on the beach makes a direct and consistent approach to the cliff unfeasible. On the other hand, the effect could get lost among other activities taking place on the beach, making it difficult for us to determine whether the response was a result of our approach or another activity.

In relation to the behaviors exerted by burrowing parrots towards the experimental approach, flying was the primary escape behavior with ~45% of the individuals fleeing within sight of the observer as seen in other studies (Sastre et al. 2009; Schlacher et al. 2013). However, ~40% responded to human approaches. This dichotomy proposes two scenarios with different energy investments. Remaining on the site supposes that individuals do not perceive a risk that outweighs the energetic cost of moving away. Also, this response was more frequent during the last stage of the breeding season, indicating that the reproductive factor could be a major constraint in the decision to flee. This might suggest that the species prioritizes the investment of energy in their broods rather than investing energy on escaping under a disturbance. For individuals who fly, this response could reflect the presence of alternative sites where to move and take cover or that the costs of moving are small. Whatever the cause, burrowing parrots are showing plasticity to choose whether to move or remain in their nest towards human disturbances. The species might be taking advantage of urban sites' services, such as infrastructure providing refuges or the absence of major predators. We did not record focal individuals entering their burrows in response to the experimental approach. Moroni et al. (2017) obtained a similar result where breeding burrowing Owl fear behavior (i.e., retreat to the burrow) was not influenced by human presence. The absence of this behavior in our study could

support the hypothesis that burrowing parrots do not perceive human approaches as a lethal threat.

We did not find an effect of our experimental approach on reproductive parameters. Furthermore, these parameters agree with those reported for the colony of El Cóndor (Masello and Quillfeldt 2002). This could be related to the nesting features of the studied species, as some burrows can reach up to 3 m deep (Masello and Quillfeldt 2012), thus giving burrowing parrot some advantages against predators (Kight and Swaddle 2007). However, it should be noted that our analysis included a small sample of nests. Furthermore, the type and magnitude of the disturbance might not be enough to alter the species' breeding behavior or any associated parameter (i.e., hatching or fledging successes). Experiences with other types of disturbance (e.g., vehicles, predator simulator) could clarify this matter.

Based on a combination of behavioral and reproductive traits, our results suggest that the burrowing parrots that nest in Las Grutas seem to be tolerant of human activities. Burrowing parrots do not modify their risk-taking behavior during their breeding season, which overlaps in time and space with the above referred human activities. We know that behavioral responses may not reflect the consequences of human disturbance (Gill et al. 2001). Therefore, we included in this study the effect on reproductive parameters which allowed us to draw better conclusions about the disturbance perceived by burrowing parrots. Studies addressing physiological responses must be undertaken to understand the extent of human disturbance in the burrowing parrot in a comprehensive way.

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