Ibis (2009), **151**, 145–150

Nest-site fidelity and cavity reoccupation by Blue-fronted Parrots *Amazona aestiva* in the dry Chaco of Argentina

IGOR BERKUNSKY* & JUAN C. REBOREDA
Departamento de Ecología, Genética y Evolución, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires. Pabellón II Ciudad Universitaria, C1428EGA Buenos Aires, Argentina

The frequency of cavity reoccupation in secondary cavity nesters depends on several factors including quality of cavities, degree of nest-site fidelity, competition with other cavity nesters and availability of new cavities. Blue-fronted Parrots *Amazona aestiva* are secondary cavity nesters that live in subtropical forests and savannas of central South America. We examined the characteristics of the trees and cavities used by this species in a protected area of the dry Chaco of Argentina and estimated nest-site fidelity and cavity reoccupation. We also assessed whether the probability of cavity reoccupation was associated with cavity characteristics and nesting success during the previous year. Nest-site fidelity of banded females was 68% and cavity reoccupation by banded and unbanded individuals 62%. Probability of reoccupation was associated with wall thickness and depth of the cavity, and was lower if the nest failed the previous year than if it was successful. The high rate of cavity reoccupation in Blue-fronted Parrots is largely attributable to strong nest-site fidelity and may reflect preferences for cavities whose characteristics are associated with higher nesting success.

Keywords: breeding success, competition, nest characteristics, Psittacines, South America.

Populations of secondary cavity nesters (species that cannot excavate their own cavities) are often limited by the availability of suitable cavities (Brawn & Balda 1988, Martin & Li 1992, Newton 1998), resulting in competition for cavities and their reoccupation by the same or by different individuals. The frequency of cavity reoccupation depends on a number of factors including quality of cavities, extent of nest-site fidelity, degree of competition for cavities with other cavity nesters and availability of new cavities (Ingold 1991). Some species of cavity nester have low rates of cavity reoccupation, probably because old cavities have higher rates of predation or higher ectoparasite loads than new ones (Sonerud 1989, Miller 2002, Mazgajski 2007). Thus, high rates of cavity reoccupation are usually considered indirect evidence of low cavity availability (Aitken & Martin 2004).

In Neotropical parrots, the frequency of cavity reoccupation appears quite variable. Some species have a low probability of cavity reoccupation (Enkerlin-Hoeflich 1995, Renton & Salinas-Melgoza 1999), and nests in new cavities have lower depredation rates than nests in older ones (Brightsmith 2005). In contrast, other studies have reported high rates of cavity reoccupation that are usually associated with low availability of cavities (Heinsohn *et al.* 2003, White *et al.* 2005, Sanz & Rodriguez-Ferraro 2006). Most of these studies were conducted with unringed individuals and therefore could not determine whether cavities were reoccupied by the same or by different individuals. The few studies conducted with ringed individuals have found that high rates of cavity reoccupation were associated with high nest-site fidelity (Snyder *et al.* 1987, Waltman & Beissinger 1992).

The Blue-fronted Parrot *Amazona aestiva* lives in subtropical forests and savannas of central South America. Like all Amazon parrots, it is a secondary cavity nester (Forshaw 1989, Ribas *et al.* 2007). Populations of this species are declining, mainly as a result of habitat transformation (deforestation and selective logging), and chick harvesting for the pet trade

*Corresponding author.
Email: igorberkunsky@yahoo.com.ar

(Bucher *et al.* 1992, del Hoyo *et al.* 1997, Fernandes Seixas & Mourao 2002). Almost all Blue-fronted Parrots in Argentina, Paraguay and Bolivia breed in the dry Chaco forest (Beissinger & Bucher 1992). This forest is classified as vulnerable, and a high priority for conservation in the Neotropics (Dinerstein 1995). At present, the dry Chaco suffers annual deforestation rates of 0.9–5% (Manghi *et al.* 2004, Zak *et al.* 2004, Boletta *et al.* 2006). Increasing deforestation and selective logging in the Chaco region are probably reducing the number of cavities for Blue-fronted Parrots outside protected areas.

A previous study of cavity reoccupation by Blue-fronted Parrots was conducted in the Pantanal region of Brazil (Fernandes Seixas & Mourao 2002). However, this study did not analyze cavity characteristics associated with cavity reoccupation and was not conducted with ringed individuals, so could not establish whether the same or different individuals reoccupied the cavities. In the present study, we describe the characteristics of cavities used by Blue-fronted Parrots in a protected area of the dry Chaco in Argentina. We estimated nest-site fidelity of ringed females and the proportion of cavities that were reoccupied in consecutive years by ringed and unringed individuals. We also assessed whether cavity characteristics and nesting success were associated with probability of reoccupation. These results are compared with those obtained from studies of other species of the *Amazona* genus.

METHODS

Study site

The study was carried out at Loro Hablador Provincial Park and neighbouring areas (25°50′S, 61°90′W, 170 m asl) in the Chaco province, Argentina. The study area is a continuous dry forest dominated by White Quebracho *Aspidosperma quebracho-blanco* and Red Quebracho *Schinopsis lorentzii*. Climate is dry subtropical, with a marked seasonality (75% of the 590 mm average annual rainfall occurs from November to March) and a long dry season (April to October).

Data collection

Data were collected from early October to late February in five consecutive breeding seasons (2002–03 to 2006–07). In each breeding season we searched intensively for Blue-fronted Parrot nests. We found nests mainly by observing the behaviour of breeding pairs. After locating a potential nest (a tree with a cavity and parrot activity), we reached the entrance hole using climbing equipment. Nests were marked with numbered plastic plates attached to the main trunk. For each nest we collected the following information: tree species, diameter at breast height (DBH), diameter at entrance hole height (DEH), height of the entrance hole, minimum and maximum diameter of the entrance hole, internal diameter and depth of the cavity and thickness of cavity wall (estimated as the difference between external and internal diameters).

Nests were monitored regularly (on average every 3 days) until the nest failed or the chicks fledged. We considered that the nest had been predated if the whole nest content disappeared between two consecutive visits, and that it had been abandoned if the eggs were cold or the chicks were dead. The main cause of nest abandonment was heavy rain. To facilitate the regular inspection of nest content, in the majority of the nests (94/98) we partially opened the cavity by making a hole near its bottom. The hole was closed using a concrete lid fixed with wire to the trunk. During the breeding seasons 2004–05, 2005–06 and 2006–07, we captured the incubating bird in 20 nests. In most cases, we captured the bird by hand immediately after removing the lid used to fix the hole as the incubating bird remained in the nest during our nest inspection. We banded the bird with a numbered aluminium ring and took a small blood sample (approximately 50 μL) for sex determination (see below) by puncturing the brachial vein with a 29G needle. The blood sample was collected in a heparinized capillary tube and stored in 500 μL of lysis buffer. None of the captured females abandoned the nest.

Cavity reoccupation analysis

Cavity reoccupation applies to cases where the same cavity was used in more than 1 year. Because most Parrots in our study population were unringed, it was often not possible to know whether the cavity was reoccupied by the same or by different individuals. Nest-site fidelity was assumed in those cases where the cavity was reoccupied by at least one of the members of a pair that occupied the cavity in previous years. A cavity was considered to be occupied if a clutch was initiated. Each breeding season we recorded whether the cavities that were occupied during previous breeding seasons were available or not. Cavities became unavailable mainly when the tree, or the portion of

Table 1. Main characteristics (mean ± SE) of cavities used as nest by Blue-fronted Parrots. Sample sizes (number of trees) are indicated in parentheses.

Tree and cavity characteristics	Mean ± SE (*n*)	Range
Tree height, m	11.1 ± 2.3 (37)	6–16
DBH, cm	50.6 ± 9.6 (86)	32–76
DEH, cm	45.5 ± 10.1 (81)	26–82
Height of entrance hole, m	5.88 ± 1.25 (80)	2.9–10.0
Depth of cavity, m	1.49 ± 0.99 (85)	0.3–4.5
Maximum diameter of entrance hole, cm	16.2 ± 11.3 (78)	6–79
Minimum diameter of entrance hole, cm	7.9 ± 2.3 (78)	4–15
Thickness of cavity wall, cm	11.3 ± 4.1 (80)	1.8–22
Internal diameter of cavity, cm	22.7 ± 6.4 (80)	14–57

the tree that contained the cavity, fell down. The rate of cavity reoccupation in consecutive years was estimated as the number of cavities with laying at years n and $n - 1$, divided by the number of cavities with laying at year $n - 1$ that were still available in year n. Similarly, the rate of cavity reoccupation was determined every 2 years as the number of cavities with laying in years n and $n - 2$ and without laying at year $n - 1$, divided by the number of cavities with laying at year $n - 2$ and without laying at year $n - 1$ that were still available at year n.

The rate of cavity reoccupation by Blue-fronted Parrots was compared with that of nine other species of the *Amazona* genus from the Neotropics and the Caribbean region. We only considered species for which a minimum of seven nests had been evaluated (for other species there were data of cavity reoccupation but from only one or two nests).

Genetic sex determination

All trapped Parrots ($n = 20$) were sexed using the different size of an intron within the highly conserved chromo-helicase-DNA binding protein (CHD) gene (Ellegren 1996). DNA was extracted from blood samples using a standard ethanol protocol (Miller *et al.* 1988) and amplified using F2 and R2 primers (Quintana *et al.* 2003). PCR amplifications were performed in 10 μL reaction volumes using 50–100 ng of DNA template, 0.5 μM forward and reverse primers, 0.25 mM dNTPs, 2.5 mM $MgCl_2$ and 0.25 units of Invitrogen Taq-Polymerase. Annealing temperatures were set at 50 °C and repeated for 30 cycles. PCR products were separated in 2% agarose gels stained with ethidium bromide. The presence of one band indicated males (ZZ), and two bands indicated females (ZW).

Statistical analysis

Data were tested for normality (Kolmogorov–Smirnov test) and are presented as means ± 1 SE. Statistical tests were two-tailed with a significance level of $\alpha = 0.05$. We used backward stepwise logistic regression to evaluate which nest characteristics were associated with nest reoccupation or nest success, and contingency tables to evaluate whether birds were more likely to reoccupy successful nests than failed nests. Because some cavities were reoccupied more than once, to avoid pseudoreplication a systematic data-selection criterion was used to select a sub-sample of cavities for analyses of nest-site characteristics and their association with probability of reoccupation or nesting success, such that individual cavities were included only once in the analyses.

RESULTS

A total of 180 nesting attempts were followed during the study ($n = 39$ in 2002–03, $n = 36$ in 2003–04, $n = 43$ in 2004–05, $n = 39$ in 2005–06, and $n = 23$ in 2006–07). These nesting attempts occurred in 98 different cavities, 82 (84%) in White Quebracho, 15 (15%) in Red Quebracho and one in *Bumelia obtusifolium*. Most cavities (78%) were in living trees. Table 1 shows the main tree and cavity characteristics.

First nesting attempts occurred during the first half of October and last ones during the first half of December, modal clutch size was four eggs ($n = 82$ nests, range 2–6 eggs), incubation started after the laying of the second egg and lasted 28.2 ± 1.8 days ($n = 82$ nests), and chicks remained in the nest 61.0 ± 5.2 days ($n = 93$ nests).

All individuals captured in the nest during incubation ($n = 20$) were females. Average body mass

Table 2. Cavity reoccupation in *Amazona* parrots. The percentage of reoccupation was calculated following the same criteria used in this paper (see Methods). The number of cavities in each study is given in parentheses.

Species	Location	Habitat type	Type of cavity	% of reoccupation (*n*)
Amazona aestiva[1]	Brazil	Savannah	Tree	38 (78)
Amazona aestiva[2]	Argentina	Dry deciduous forest	Tree	62 (98)
Amazona agilis[3]	Jamaica	Rainforest	Tree	41 (17)
Amazona autumnalis[4]	Mexico	Semi-deciduous forest	Tree	11 (19)
Amazona collaria[3]	Jamaica	Rainforest	Tree	13 (8)
Amazona finschi[5]	Mexico	Dry deciduous forest	Tree	7 (54)
Amazona oratrix[4]	Mexico	Semi-deciduous forest	Tree	35 (23)
Amazona ochrocephala[6]	Panama	Tropical Dry forest	Tree	74 (19)
Amazona viridigenalis[4]	Mexico	Semi-deciduous forest	Tree	2 (14)
Amazona vittata[7]	Puerto Rico	Rainforest	Tree/Nest-box	High

[1]Fernandes-Seixas & Mourao (2002), [2]this study, [3]Koenig (2001), [4]Enkerlin-Hoeflich (1995), [5]Renton & Salinas-Melgoza (1999), [6]Rodríguez Castillo & Eberhard (2006), [7]White *et al.* (2005).

of the captured females was 412 ± 31 g ($n = 17$). One ringed female was predated within the cavity the same breeding season she was captured. Twelve of the 19 remaining females (63%) reused the same cavity the following year, and one female did not reuse the cavity the following year but did so 2 years later. Combining these data, nest-site fidelity by ringed females was 68% (13/19 females). During the study period, we did not observe any ringed female using a cavity different from the one used in previous years.

Cavity reoccupation in consecutive years by ringed or unringed individuals was 55% (83/150 cases), whereas every second and third year it was 7% (8/119 cases) and 3% (2/77 cases), respectively. Overall cavity reoccupation, including consecutive reoccupancy and reoccupancy in subsequent years, was 62% (93/150 cases).

In 12 cases, cavities were reoccupied by a different species, three by Ferruginous Pygmy-owl *Glaucidium brasilianum*, two by Tropical Screech-owl *Otus choliba*, four by Great-rufous Woodcreeper *Xiphocolaptes major*, two by Narrow-billed Woodcreeper *Lepidocolaptes angustirostris*, and one by Blue-crowned Parakeet *Aratinga acuticaudata*. In one of these cases (Tropical Screech-owl), Blue-fronted Parrots ejected the other species from the cavity. In the other cases, no agonistic interactions between Blue-fronted Parrots and the species that occupied the cavity were observed.

Backward stepwise logistic regression modelling of the binary cavity reoccupation variable identified cavity wall thickness (–2 log likelihood = 11.1, $P < 0.001$) and cavity depth (–2 log likelihood = 4.4, $P < 0.05$) as the best predictors, while minimum diameter of the entrance hole showed a tendency towards significance (–2 log likelihood = 3.6, $P = 0.06$). A similar analysis of a binary nesting success variable identified DBH (–2 log likelihood = 9.9, $P < 0.01$), cavity wall thickness (–2 log likelihood = 5.3, $P < 0.05$) and height of the entrance hole (–2 log likelihood = 4.3, $P < 0.05$) as significant predictors. Probability of cavity reoccupation was lower if the nest failed the previous year than if it was successful (failed nests: 17/33, successful nests: 65/82, $\chi^2_1 = 7.6$, $P < 0.01$).

Table 2 shows the rates of cavity reoccupation for all Amazon parrots studied.

DISCUSSION

Although several studies have examined cavity reoccupation in Amazon parrots (Table 2), none were conducted on ringed individuals and so it could not be determined if cavities were reoccupied by the same or by different individuals. This study shows that 68% of ringed females used the same cavity 1 or 2 years later. This was similar to the percentage of cavities reoccupied by ringed and unringed individuals (63%). Similarly, the few studies conducted with ringed individuals of other parrot genera found that high rates of nest-site fidelity were associated with high rates of cavity reoccupation (Snyder *et al.* 1987, Waltman & Beissinger 1992).

The rate of cavity reoccupation in our study was higher than the 38% observed in Blue-fronted Parrots in Pantanal savannas (Fernandes Seixas & Mourao 2002). This difference could be attributable to the rapid decline in the quality of Pantanal cavities, where one third of the cavities were in dead palm trees (Fernandes Seixas & Mourao 2002). When considering the other Amazon species, only the Panama Amazon *Amazona ochrocephala panamensis* shows rates of cavity reoccupation similar to that recorded in our study (Rodríguez Castillo & Eberhard 2006). The rate of cavity reoccupation for the other Amazon species varies from 7% in Lilac-crowned Parrot *Amazona finschi* (Renton & Salinas-Melgoza 1999) to 41% in Black-billed Parrot *Amazona agilis* (Koenig 2001).

It has been proposed that the reoccupation of cavities may increase the probability of nest predation or the ectoparasite load of chicks (Miller 2002, Mazgajski 2007). Therefore, high rates of cavity reoccupation are considered by some researchers to be indirect evidence of low availability of cavities (Aitken & Martin 2004). Previous studies of parrots have reported competition for cavities with conspecifics (Heinsohn *et al.* 2003) or with other cavity nesters (Snyder *et al.* 1987, Prestes *et al.* 1997). However, we only observed one case of interspecific competition and did not observe conspecific competition for cavities (e.g. agonistic interactions between pairs). Furthermore, approximately 45% of the available cavities in a given year were not reoccupied by Blue-fronted Parrots in our study. Thus, it seems unlikely that the high rate of cavity reoccupation was the result of low availability of cavities. Even though our study did not find clear evidence of either conspecific or heterospecific competition for cavities, because rates of deforestation and selective logging in the dry Chaco (the most suitable nesting habitat for Blue-fronted Parrots) are very high, a shortage of cavities may occur in the near future.

The probability of cavity reoccupation was higher if the nest was successful the previous breeding season than if it failed, and some cavity characteristics were associated with nesting success and likelihood of reoccupation. Deep cavities with thick walls might reduce fluctuations in temperature (Aitken & Martin 2004). These results indicate that Blue-fronted Parrots tend to reoccupy cavities with characteristics associated with a higher probability of nesting success, as has been found with other cavity nesters such as Collared Flycatcher *Ficedula albicollis* (Mitrus *et al.* 2007).

We are grateful to R. Rojas, R. Ruggera, J. Carrera, B. Charpin, C. de la Fourniére, L. Pagano, M.S. López Santoro, and B. Mahler for partnership and collaboration during field and laboratory work. We also thank the Dirección de Fauna, Parques y Ecología of Chaco Province for logistical support. I.B. was supported by fellowships from Comisión de Investigaciones Científicas de la Provincia de Buenos Aires (CIC), and Consejo Nacional de Investigaciones Científicas y Técnicas de Argentina (CONICET). J.C.R. is Research Fellow of CONICET. Our study was partially financed by Parrot People Foundation, The World Parrot Trust, Parrots International, The Amazona Society and individual donations.

REFERENCES

Aitken, K.E.H. & Martin, K. 2004. Nest cavity availability and selection in aspen–conifer groves in a grassland landscape. *Can. J. Zool.* **34**: 2099–2109.

Beissinger, S.R. & Bucher, E.H. 1992. Can parrots be conserved through sustainable harvesting? *BioScience* **42**: 164–173.

Boletta, P.E., Ravelo, A.C., Planchuelo, A.M. & Grilli, M. 2006. Assessing deforestation in the Argentine Chaco. *Forest Ecol. Manag.* **228**: 108–114.

Brawn, J.D. & Balda, R.P. 1988. Population biology of cavity nesters in Northern Arizona: Do nest sites limit breeding densities? *Condor* **90**: 61–71.

Brightsmith, D. 2005. Competition, predation and nest niche shifts among tropical cavity nesters: ecological evidence. *J. Avian Biol.* **36**: 74–83.

Bucher, E.H., Saravia, C., Miglietta, S. & Zaccagnini, M.E. 1992. Status and management of the Blue-fronted Amazon Parrot in Argentina. *Psittascene* **4**: 3–6.

Dinerstein, E. 1995. *A Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean*. Washington, DC: WWF Fund and The World Bank.

Ellegren, H. 1996. First gene on the avian W chromosome (CHD) provides a tag for universal sexing of non-ratite birds. *Proc. R. Soc. Lond. B* **263**: 1635–1641.

Enkerlin Hoeflich, E.C. 1995. *Comparative Ecology and Reproductive Biology of Three Species of Amazon Parrots in Northeastern Mexico*. Ph.D. Thesis, Texas A&M University.

Fernandes Seixas, G.H. & Mourao, G.D. 2002. Nesting success and hatching survival of the Blue-fronted Amazon (*Amazona aestiva*) in the Pantanal of Mato Grosso do Sul, Brazil. *J. Field Orn.* **73**: 399–409.

Forshaw, J.M. 1989. *Parrots of the World*. 3rd edn. Melbourne: Lansdowne Editions.

Heinsohn, R., Murphy, S. & Legge, S. 2003. Overlap and competition for nest holes among Eclectus Parrots, Palm Cockatoos and Sulphur-crested Cockatoos. *Aust. J. Zool.* **51**: 81–94.

del Hoyo, J., Elliot, A. & Sargatal, J. (eds) 1997. *Handbook of the Birds of the World*, Vol. 4. Barcelona: Lynx Edicions.

Ingold, D.J. 1991. Nest-site fidelity in Red-headed and Red-bellied Woodpeckers. *Wilson Bull.* **103**: 118–122.

Koenig, S.E. 2001. The breeding biology of Black-billed Parrot *Amazona agilis* and Yellow-billed Parrot *Amazona collaria* in Cockpit Country, Jamaica. *Bird Conserv. Int.* **11**: 205–225.

Manghi, E., Strada, M., Montenegro, C., Bono, J., Parmuchi, M.G. & Gasparri, I. 2004. *Mapa Forestal. Provincia del Chaco. Actualización 2004*. Buenos Aires: Secretaría de Ambiente y Desarrollo Sustentable.

Martin, T.E. & Li, P. 1992. Life history traits of open- vs. cavity-nesting birds. *Ecology* **73**: 579–592.

Mazgajski, T.D. 2007. Effect of old nest material on nest site selection and breeding parameters in secondary hole nesters – A review. *Acta Ornithol.* **42**: 1–14.

Miller, K.E. 2002. Nesting success of the Great Crested Flycatcher in nest boxes and in tree cavities: are nest boxes safer from nest predation? *Wilson Bull.* **114**: 179–185.

Miller, S.A., Dykes, D.D. & Polesky, H. F. 1988. A simple salting out procedure for extracting DNA from human nucleated cells. *Nucleic Acids Res.* **16**: 1215.

Mitrus, C., Walankiewicz, W. & Czeszczewik, D. 2007. Frequency of nest-hole occupation and breeding success of Collared Flycatchers *Ficedula albicollis*. *Ibis* **149**: 414–418.

Newton, I. 1998. *Population Limitation in Birds*. San Diego: Academic Press.

Prestes, N.P., Martinez, J., Meyrer, P.A., Hansen, L.H. & de Negri Xavier, M. 1997. Nest characteristics of the Red-spectacled Amazon *Amazona pretrei* Temminck, 1830 (Psittacidae). *Ararajuba* **5**: 151–158.

Quintana, F., Somoza, G., Uhart, M., Cassara, C., Gandini, P. & Frere, E. 2003. Sex determination of adult Rock Shags by molecular sexing and morphometric parameters. *J. Field Orn.* **74**: 370–375.

Renton, K. & Salinas-Melgoza, A. 1999. Nesting behavior of the Lilac-crowned Parrot. *Wilson Bull.* **111**: 488–493.

Ribas, C.C., Tavares, E.S., Yoshihara, C. & Miyaki, C.Y. 2007. Phylogeny and biogeography of Yellow-headed and Blue-fronted Parrots (*Amazona ochrocephala* and *Amazona aestiva*) with special reference to the South American taxa. *Ibis* **149**: 564–574.

Rodríguez Castillo, A.M. & Eberhard, J.R. 2006. Reproductive behavior of the Yellow-crowned Parrot (*Amazona ochrocephala*) in Western Panama. *Wilson J. Orn.* **118**: 225–236.

Sanz, V. & Rodriguez-Ferraro, A. 2006. Reproductive parameters and productivity of the Yellow-shouldered Parrot on Margarita island, Venezuela: a long-term study. *Condor* **108**: 178–192.

Snyder, N.F.R., Wiley, J.W. & Kepler, C.B. 1987. *The Parrots of Luquillo. Natural History and Conservation of the Puerto Rican parrot.* Los Angeles: Western Foundation of Vertebrate Zoology.

Sonerud, G.A. 1989. Reduced predation by pine martens on nests of Tengmalm's Owl in relocated boxes. *Anim. Behav.* **37**: 332–334.

Waltman, J.R. & Beissinger, S.R. 1992. Breeding behavior of the Green-rumped Parrotlet. *Wilson Bull.* **104**: 65–84.

White, T.H., Jr, Abreu-González, W., Toledo-González, M. & Torres-Báez, P. 2005. Artificial nest cavities for *Amazona* parrots. *Wildl. Soc. Bull.* **33**: 756–760.

Zak, M.R., Cabido, M. & Hodgson, J.G. 2004. Do subtropical seasonal forests in the Gran Chaco, Argentina, have a future? *Biol. Cons.* **120**: 589–598.

Received 23 June 2008; revision accepted 17 September 2008.