

Predation on artificial nests in open habitats of central Brazil: effects of time and egg size

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Abstract: The accuracy of artificial nests in representing natural patterns of nest predation has been widely studied in temperate regions and egg size is one of the most tested sources of bias. In the neotropics, experiments with artificial nests usually used larger than natural eggs, despite suggestions in literature that the eggs should be similar to those of the local species. Here, we tested the hypothesis of spatial-temporal variation in predation risk of artificial nests in relation to egg size. We used quail (*Coturnix coturnix*; large), Chestnut-bellied Seed-finch (*Oryzoborus angolensis*; small) and plasticine (both sizes) eggs placed in artificial nests. We analyzed daily nest survival using models in the Program MARK. The best-fit model included the effects of egg size and the reproductive period on daily survival of artificial nests. Nests with large eggs had greater Daily Survival Estimates (DSE) than nests with small eggs during two times and DSE were smaller early in the reproductive period. DSE of 0.82 (95% CI = 0.76 to 0.86) and 0.91 (0.87 to 0.93) were recorded for large eggs at the beginning and end periods compared to 0.72 (0.65 to 0.78) and 0.84 (0.79 to 0.88) for small eggs. Birds were more important predators (40% of records) than mammals and reptiles based on signs left on the plasticine eggs. Our results support the hypothesis that larger eggs are less depredated than small ones in artificial bird nests, even when main predators (birds) are different from those commonly observed in the Neotropics (mammals and reptiles). However, controlling the egg size in experiments with artificial nests may not be sufficient to obtain similar time patterns observed in natural nests studied in the *Cerrado*.

Keywords: bird, *Cerrado*, neotropical savanna, nest success, reproduction.

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Resumo: A acurácia de ninhos artificiais em representar padrões naturais de predação de ninhos foi amplamente estudada em regiões temperadas, sendo o tamanho do ovo uma das fontes de erro mais testadas. Nos Neotrópicos, os experimentos com ninhos artificiais geralmente usaram ovos maiores que os naturais, apesar da literatura indicar a necessidade do uso de ovos semelhantes aos das espécies locais. Aqui, testamos hipóteses sobre variação espaço-temporal no risco de predação de ninhos artificiais em função do tamanho do ovo. Para isso, usamos ninhos artificiais com ovos de Codorna (*Coturnix coturnix*; grandes), Curió (*Oryzoborus angolensis*; pequenos) e plasticina (ambos tamanhos). Analisamos a sobrevivência diária dos ninhos através de modelos gerados no Programa MARK. O modelo melhor ajustado aos dados incluiu o efeito do tamanho do ovo e do período reprodutivo na sobrevivência diária dos ninhos artificiais. Ninhos com ovos grandes tiveram maiores Estimativas de Sobrevivência Diária (ESD) durante os dois períodos, além disso, as ESD foram menores no início do período reprodutivo. ESD de 0,82 (95% IC = 0,76 a 0,86) e 0,91 (0,87 a 0,93) foram registradas para ovos grandes no início e fim da estação reprodutiva, comparado com 0,72 (0,65 a 0,78) e 0,84 (0,79 a 0,88) registradas para ovos pequenos. As aves foram predadores mais importantes (40% dos registros) que os mamíferos e répteis, de acordo com as marcas deixadas nos ovos de plasticina. Nossos resultados dão suporte à hipótese de que ovos grandes são menos predados do que pequenos, mesmo os principais predadores (Aves) tendo sido diferentes do comentado observado nos Neotrópicos (Mamíferos e Répteis). No entanto, controlar o tamanho dos ovos nos experimentos com ninhos artificiais pode não ser suficiente para se obter padrões temporais similares ao observado em ninhos naturais no *Cerrado*.

Palavras-chave: aves, *Cerrado*, savana neotropical, sucesso de ninhos, reprodução.

Introduction

In the last four decades, experiments with artificial bird nests have been used to test hypotheses of nest predation patterns (reviews in Major & Kendal 1996, Moore & Robinson 2004). However, artificial nests differ from natural nests in important ways, including appearance (nest shape and color), scent, egg size and parental activity (Major & Kendal 1996), which may result in biased estimates of true predation rates (Roper 1992, Haskell 1995, Maier & DeGraaf 2000). These problems have directed the use of artificial nests to test more restricted hypotheses such as to predict relative impacts between habitat types, or for comparisons between artificial and natural nests (Pärt & Wretenberg 2002, Batáry & Báldi 2005, Boyle 2008, Ryder et al. 2010). The effectiveness of artificial nest experiments depend on local and specific agents, and each characteristic of the nest must be tested before local hypotheses on conservation and ecological patterns are evaluated (Major & Kendal 1996).

Predation on natural bird nests is a frequent cause of low reproductive success in the neotropics (Stutchbury & Morton 2001). This is also true in open areas of the *Cerrado* (neotropical savanna), where predation results in 70% from 90% of nests lost (Lopes & Marini 2005, França & Marini 2009b, Borges & Marini 2010). In forests, the main nest predators appear to be mammals, snakes and lizards (Robinson & Robinson 2001, Stake et al. 2004, Robinson et al. 2005). In contrast, in some areas in the *Cerrado*, birds were the main predators (França et al. 2009). Overall, predation in the *Cerrado* habitats tended to increase throughout the reproductive period (Borges & Marini 2010), decrease during nest development (França & Marini 2009b), and differ between habitats and microhabitats (França & Marini 2009a, Borges & Marini 2010). These studies show the importance of predation for population dynamics of neotropical birds and so experiments with artificial nests may be important to understand spatial and temporal patterns of reproductive success.

The few neotropical studies with artificial nests or both natural and artificial nests were conducted in closed forested areas (Roper 2000, Robinson et al. 2005, Alvarez & Galetti 2007), where birds were not an important set of predators, or in open areas of *Cerrado*, but not controlling for egg sizes (França & Marini 2009a). As with natural nests, predation risk was influenced by habitat or nest characteristics (França & Marini 2009a, Chiarello et al. 2008, Boyle 2008, Alvarez & Galetti 2007, Robinson et al. 2005). Experiments with artificial nests in the neotropics detect spatial and temporal variation in nest predation risk, yet how these effects resemble those observed for natural nests are unknown. Furthermore, egg size, one of the most tested influences on predation rates (Haskell 1995, Maier & DeGraaf 2000, Berry & Lill 2003) was usually overlooked in neotropical studies.

In our study we used the available literature on predation of natural and artificial nests in neotropics to test hypotheses about variation in the predation risk of artificial nests. The tested hypotheses were: (1) predation on artificial nests with large eggs will be less than that on nests with small eggs (Roper 1992, Alvarez & Galetti 2007); (2) the risk of predation will increase over time during the reproductive season, as observed in some studies with natural nests in neotropical areas (Borges & Marini 2010, Duca & Marini 2005); (3) predation risk will be greater in shrubs habitat than in trees, because predation tends to be greater in savanna than in forest (see Duca & Marini 2005, Robinson et al. 2000, França & Marini 2009b, Borges & Marini 2010).

Materials and Methods

1. Study area

Our study was conducted in a *Cerrado* fragment (Neotropical savanna) of central Brazil (15° 45' S, 48° 04' W). The area comprises

open-*cerrado*, gallery forests and plantations of *Eucalyptus* sp. The open-*cerrado* areas have a grass matrix with sparse Shrub and trees (Ribeiro & Walter 1998). The gallery forests are perennial closed forests which follow a stream course. The eucalyptus plantations were clear cut, but have been abandoned for at least 10 years and *cerrado* is in regeneration. In this habitat we observed the occurrence of common birds in the open-*cerrado* (pers. obs.), however we did not establish relative abundances. The open-*cerrado* and plantations had no canopy formation.

2. Experiment design and data sampling

We built artificial open-cup nests with clusters of local grasses and sewing thread to mimic the shape and size of Lesser Elaenia nests (*Elaenia chiriquensis*, Lawrence 1865). Nests of this elaenia are the most abundant and found in the region during the time of this study. Her nests are cups with grass stems and spider webs, at an average height of 1.5 m in shrubs and trees (Medeiros & Marini 2007). The Lesser Elaenia was also very common in the study area during the breeding season (L.F. França, pers. obs.). Our artificial nests were dipped in a mixture of water and clay and dried in the sun. Afterwards, to reduce human scent, we used latex gloves when touching the nests and eggs (Whelan et al. 1994). Quail eggs (*Coturnix coturnix*, Linnaeus 1758) were our large egg treatment (25 to 30 mm in length) and Chestnut-billed Seed-finch eggs (*Oryzoborus angolensis*, Linnaeus 1766) the small egg treatment (18 to 20 mm in length). The latter are similar in size and color to those of most local passerine eggs. Also, artificial eggs made of plasticine (white wax modeling clay, ACRILEX®) were used to identify predators based on the marks left on the eggs.

We used nests with large eggs (one quail egg and one plasticine egg of the same size, shape and colors) and nests with small eggs (one Chestnut-billed Seed-finch egg and one plasticine egg of the same size, shape and colors) to test the effects of egg size on nest predation risk. Nest and egg combinations were placed from 28 October to 12 November and 9 December to 24 December 2007, to test the temporal effects of the reproductive season. These periods were used to represent the beginning and end of the songbird breeding season. We placed the nests in two habitats, open-*cerrado* and *Eucalyptus* plantations, to test the effects of habitat type (open shrub vs. open forest) on the risk of predation. A total of 160 nests were used: 20 nests of each egg size per habitat during each time period. We use one nest transect for each habitat and the transects were separated by >700 m and were >50 m from the habitat edge. Nests were placed every 25 m alternating large egg and small egg nests. Eggs were placed in the nests 48 h after placing the nests in the field to avoid possible influence due to the researcher. The nest installation took some time, however, placing the eggs was fast and we tried to avoid pauses near the nests.

Nests were monitored every three or four days until they disappeared or 15 days, whichever came first. This time interval was based on the incubation period for many songbirds in the *Cerrado* (L. F. França, pers. comm.). We considered damaged nests, or with at least one broken or missing egg as a predation event. V-shaped marks on the plasticine eggs were considered to be made by birds. Marks showing different types of teeth, canines or incisors were attributed to mammals. Marks in an inverted U-shape, as well as uniform and sharp teeth imprinting were considered to be made by reptiles.

3. Data analysis

Following the information-theoretic approach (Burnham & Anderson 1998), we developed 11 *a priori* candidate models to test our initial hypotheses. These models evaluate the potential effect of egg size (large or small), period (beginning or end), or habitat type

(open-cerrado or *Eucalyptus* plantation). We considered simple linear models containing only one covariate to test the first three hypotheses independently. We used multiple linear additive models (egg + period, egg + habitat, habitat + period or egg + habitat + period) or interactive models (egg × period, egg × habitat or egg × habitat × period) to consider the association between the previous hypotheses. A constant survival model (null model) was also included.

We used the MARK Program (White & Burnham 1999) to run General Linear Models, that estimate the daily survival of artificial nests (Dinsmore et al. 2002), and to sort candidate models based on Akaike Information Criterion adjusted for small samples (AIC_c ; Burnham & Anderson 1998). The best-fit model was the one with the lowest AIC_c value and models with $\Delta AIC_c \leq 2$ were considered to have substantial support to explain variation in the data (Burnham & Anderson 1998). We used the daily nest survival of the best-fit model to estimate nest success based on 15 days of incubation.

Results

Two of 11 candidate models received substantial support to explain daily nest survival, both including effects of egg size and reproductive period (Table 1). All other combinations of explanatory variables resulted in models with low support ($\Delta AIC_c > 2.00$) and interactive models had less support than their similar additive model. Hence, model averaging was unnecessary. The best fit model was clearly better than the null model ($\Delta AIC_c = 22.2$) and about 80% weight was in the first two models (Table 1).

We used the best-fit model (egg + period) to estimate daily nest survival, since it was more parsimonious than the second model (egg × period). Daily Survival Estimate (DSE) was 0.82 (95% CI = 0.76 to 0.86) early and 0.91 (0.87 to 0.93) late for large eggs, compared to DSE of 0.72 (0.65 to 0.78) early and 0.84 (0.79 to 0.88) late for small eggs. Therefore nests with large eggs had higher success estimates during both periods, and nest success was greater at the end of the reproductive season (Figure 1). Specifically, estimates of egg success increased for both egg sizes during breeding season, but to a greater extent for large eggs. While the difference between periods for large eggs was 0.18, the difference for small eggs was 0.07.

Plasticine eggs from 98 nests (62%) were marked. Three taxa were recognized and birds were responsible for about 40% of predation events (Table 2). However, all treatments had similar predation on both egg sizes (Table 2).

Discussion

Small eggs were preyed on more than large eggs in our experiments with artificial nests in open habitats of Neotropics, which suggests that predators are relatively small and large quail eggs are difficult to handle and consume (Roper 1992). Similar results have been reported for temperate (Maier & DeGraaf 2000, Coppedge et al. 2007) and neotropical forests (Alvarez & Galetti 2007). Comparisons

between artificial and natural nests also revealed the importance of controlling egg size (Roper 2003, Berry & Lill 2003, Burke et al. 2004, Robinson et al. 2005). The importance of other characteristics such as egg color and scent seems marginal (review in Major & Kendal 1996). Our results also support the hypothesis that egg size influences predation estimates in experimental studies with artificial nests. Moreover, our results indicate that this effect is probably common even when top predators (birds) are different from those commonly observed in other areas (mammals, snakes and lizards).

Lower predation of large eggs indicates that some predators cannot or do not take large eggs. Studies based on evidences of predation show that some small mammals are unable to consume quail eggs (Roper 1992, Haskell 1995, DeGraaf & Maier 1996, Bayne & Hobson 1999, Maier & DeGraaf 2000). Small birds, such as the Black-capped Chickadee (*Parus atricapillus*) also seem to be unable to consume quail eggs (Maier & DeGraaf 2001). Because birds seem to be important nest predators in the *Cerrado* (França & Marini 2009a, França et al. 2009), it would be important to determine if some small *Cerrado* birds cannot consume large eggs which might explain the difference in predation rates between artificial and natural nests.

Our study found a greater survival rate of artificial nests at the end of the reproductive season, regardless of egg size. A previous study showed similar tendency for large eggs (quail eggs; França & Marini 2009a). Surprisingly, studies of natural nests in the same region found declining nest survival rates as the breeding season progressed (Borges & Marini 2010, Santos 2008). Artificial nests may be inaccurate for providing absolute nest predation rates on real nests, but may be sufficient for relative comparisons (Major & Kendal 1996, Buler & Hamilton 2000, Dion et al. 2000). However, our study showed that relative predation rates of artificial nests may not be correct for determining relative trends as compared to natural

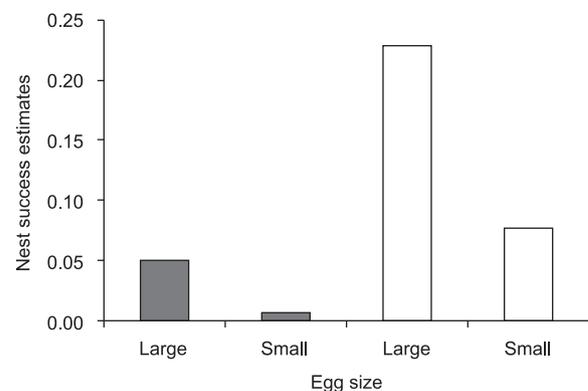


Figure 1. Success estimates of nests containing large or small eggs in the beginning (dark bars) and end (light bars) of the studied reproductive season. The equation of the best-adjusted model with one standard error in parentheses was $\text{Logit}(S_i) = 1.51(0.17) - 0.59(0.19)_{\text{egg}} + 0.75(0.19)_{\text{period}}$. We used this model to estimate nest success based on 15 days of egg exposure.

Table 1. Candidate models for estimates daily survival of artificial bird nests (models with $\Delta AIC_c \leq 10$). AIC_c is the Akaike's Information Criterion, ΔAIC_c is the difference between the AIC_c of a model and the minimum AIC_c found for the models, k is the number of parameters, and $w\text{-}AIC_c$ is the support of each model in comparison to the others.

Hypotheses	Model	AIC_c	ΔAIC_c	$w\text{-}AIC_c$	k	Deviance
1, 2	egg + period	436.44	0.00	0.50	3	430.41
1, 2	egg × period	437.59	1.15	0.28	4	429.54
1, 2, 3	egg + period + habitat	438.46	2.02	0.18	4	430.41
1, 2, 3	egg × period × habitat	442.65	6.21	0.02	7	428.50
2	period	443.98	7.54	0.01	2	439.97
2, 3	period + habitat	446.00	9.56	0.00	3	439.97

Table 2. Percentage (and number) of plasticine eggs marked by different predators in the study area.

Predator Taxon	Percentage of Marked Eggs by Egg size	
	Large (n)	Small (n)
Bird	41 (12)	40 (10)
Reptile	21 (6)	20 (5)
Mammal	14 (4)	20 (5)
Unidentified	24 (7)	20 (5)
Total	100 (29)	100 (25)

nests. That is, if natural nests do not follow the same trends over time as experimental nests, then the experimental nests do not describe what happens at natural nests. Therefore, controlling egg size in the experiments may not resolve the bias due to experimental nests. This hypothesis requires further attention in future studies on artificial nests in the *Cerrado*.

Predation rates were similar in the two habitat types despite the large differences in their structure (open shrub vs. open forest). Spatial variation in predation rates of artificial nests has been seen in similar as those in this study (Noske et al. 2008). For some passerines of the *Cerrado*, habitat type (natural vs. anthropic) or landscape characteristics (margin vs. interior) can affect nest success (Borges & Marini 2010, França & Marini 2009a). Despite comparisons with other studies, we did not reach conclusions concerning the lack of difference between habitat types in our experiment. We cannot say whether there was a discrepancy with observed for natural nests, since one of the habitats assessed (eucalyptus plantations) has no correspondence with natural habitats of the *Cerrado*.

Controlling for egg size to make experiments more realistic does not seem to be sufficient to make nest predation experiments valid in the *Cerrado*. We suggest that new studies based on simultaneous data from natural and artificial nests be developed to test the hypotheses on temporal pattern divergence between the nests (Roper 2003). Finally, it is important for new experiments to try to identify and compare predator assemblages of artificial and natural nests. This alternative may help explain specific sources of bias for the *Cerrado*, since birds were particularly important predators.

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