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Breeding patterns and habitat use in the endemic Curl-crested Jay of central Brazil

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ABSTRACT. Little is known about the life history and reproduction of the Curl-crested Jay (*Cyanocorax cristatellus*), despite its conspicuousness and endemic status, being restricted primarily to the central Cerrado biome of Brazil. From May 1999 to December 2000, we examined the sizes of home ranges and foraging and reproductive patterns in this species. Average group size was approximately 10 individuals, with average home ranges of 172 ha; during the reproductive period individuals in the group tended to stay within approximately 29 ha of active nests. These jays are dietary generalists, while the diversity of substrates and capture techniques employed showed high flexibility in resource utilization. The reproductive period was from September to March, and groups produced average clutch sizes of 5.7 eggs, but only 35% of these hatched and only 25% of the nests produced at least one fledgling. Predation was the chief cause of nesting failure, accounting for 63% of nest loss. The occurrence of large groups year-round with several individuals providing parental care and evidence of just one female laying eggs suggest that the Curl-crested Jay is a cooperative breeder with a high degree of sociality. However, further study is necessary to exclude the possibility that more than one female is laying eggs in a single nest.

SINOPSIS. **Patrones de reproducción y utilización del hábitat por *Cyanocorax cristatellus*, ave endémica al centro de Brazil**

Se conoce poco sobre la historia natural y la reproducción de *Cyanocorax cristatellus*, aunque es una especies conspícua y endémica, estando restringida principalmente al bioma del Cerrado central de Brazil. Examinamos la extensión de su distribución, junto con los patrones de forrajeo y reproductivos de mayo del 1999 hasta diciembre del 2000. El tamaño grupal promedio fué cerca de 10 individuos, con extensiones de áreas de vida de 172 ha, mientras que en el período reproductivo los individuos del grupo tendieron a quedarse alrededor de 29 ha de los nidos activos. Estas aves son generalistas alimenticios, mientras que respecto a la diversidad de substratos y de técnicas de captura empleadas mostraron una gran flexibilidad en el uso de los recursos. El período reproductivo fué de septiembre a marzo, y los grupos produjeron una nidada promedia de 5.7 huevos, pero solo 35% de estos eclosionó y solo 25% de estos nidos produjo al menos un volantón. La mayor causa del fracaso de los nidos fué la depredación, sumando 63% de la pérdida neta. La existencia de grupos grandes sostenidos a través del año con varios individuos proveyendo cuidado parental y la evidencia de una sola hembra poniendo huevos sugiere que esta especie es de reproducción cooperativo con un alto grado de socialización. Sin embargo, se necesitan más estudios para excluír la posibilidad de que más de una hembra esté poniendo sus huevos en un mismo nido.

Key words: Brazil, Cerrado, cooperative breeding, Curl-crested Jay, *Cyanocorax cristatellus*, foraging

Corvids occur from tropical forests to Antarctic tundra, and their social systems range from territorial pairs to group territories, with or without cooperative breeding and/or plural nesting (Goodwin 1986; Shank 1986). In Brazil the Corvidae is represented by eight species, all from the genus *Cyanocorax*. The Curl-crested Jay (*Cyanocorax cristatellus*) is endemic to the Cerrado biome of central Brazil, but has also been recorded in Paraguay (Ridgely and Tudor 1989) and Bolivia (Sick 1997).

The central Brazilian plateau is dominated by the Cerrado biome, containing savanna-like vegetation varied in form, ranging from dense grassland, usually with a sparse covering of shrubs and small trees, to open woodland (known as cerrado *sensu stricto*) to an almost closed woodland with a canopy height of 12–15 m (Ratter et al. 1997). This tropical biome occupies two million km^2 of central Brazil, representing 23% of the country; it is considered one of the 25 world hotspots due to an exceptional concentration of endemic species while also suffering a rapid loss of the native vegetation (Myers et al. 2000). The Curl-crested Jay is one of the 29 endemic bird species of the Cerrado biome (Silva 1995).

Despite its endemic status, conspicuous hab-

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its and evident sociality, the Curl-crested Jay is poorly known, and, to date, there have been no detailed studies of its biology and reproduction. The lack of information on almost all aspects of its biology is probably due to the difficulty of conducting studies with jays in general, given their intelligence, alertness, and secretive habits. Available information indicates only that these jays occur in groups of eight to 12 individuals, have simple vocal repertoires, prefer open areas but also use gallery forests, and seem to be nomadic during the nonreproductive season (Hardy 1969). There is also a record of them attacking wasp nests (Henriques and Palma 1998). The fact that these birds are usually seen in groups suggests a high degree of sociality.

In this first descriptive study of the Curl-crested Jay, we report on home range size, activity patterns including foraging behavior, occurrence of sociality during breeding, and reproductive characteristics and parental care.

METHODS

Study area. The study was conducted at Brasilia National Park, which comprises 32,000 hectares in central Brazil (15°43′S, 47°57′W). Data collection occurred from May 1999 to December 2000 within a well conserved 3000-ha area in the Park where the most widespread form of cerrado vegetation consisted of trees and large shrubs about 2–8 m in height, producing 10–60% canopy cover with a well developed grassy ground layer. This area, contained within a conservation unit, had few signs of human impact, but natural fires were common, as were natural nest predators. The climate is highly seasonal with a wet season from October to April (mean precipitation, 300 mm), and a dry season from May to October (mean precipitation, 30 mm; Eiten 1993). The first rains in the area usually occur in mid-September.

Home range and group size. During the study period, we captured individuals from three groups of Curl-crested Jays with Tomahawk traps (live spring traps commonly used for capturing mammals; see www.livetrap.com for details) baited with quail eggs (*Coturnix coturnix*) and placed within the tree canopy. We also used mist nets, attracting birds using playback. We marked individuals with plastic colored and metallic bands to identify them during focal observations. Each time a group was sighted, whether or not it showed defensive behavior, we marked its geographic position in 50-m stretches using GPS Garmin 12XL. We estimated home range by plotting every point where a group was seen during the whole study period (breeding and nonbreeding seasons). During each breeding attempt of a group, we also estimated the area around the nest actively occupied by the group and where individuals vocalized defensively upon sighting human intruders. We mapped the points obtained for each group in ArcView GIS 3.1 and calculated home range and breeding area defended from human intruders with the construction of polygons.

Groups were identified by the presence of marked individuals and by the re-occurrence of sightings within the same areas. We counted the number of adult individuals each time a group was sighted, especially when they were crossing a trail, and considered group size as the maximum number of individuals counted repeatedly during the study.

Activity patterns. We recorded and quantified the jays' activity patterns between December 1999 and August 2000 through focal observations from distances of 10–50 m. A focal individual was chosen randomly and monitored for as long as possible; we used only those samples lasting for more than 30 s. In one-minute intervals, we recorded the following activities: foraging, resting, preening, sentinel behavior (see definition below), interacting with others physically, or in motion (hopping or flying). We considered that foraging occurred when the bird was perched on non-exposed vegetation scanning its surroundings, hopping through vegetation or on the ground, manipulating substrate or prey, flying between these activities (Langen 1996a), or cleaning of the bill.

We considered sentinel behavior as when an individual sat on an exposed perch, with or without shading, for at least 30 s and turned its head periodically, or when other behavior, such as preening or active foraging, amounted to less than 50% of that activity period (McGowan and Woolfenden 1989; Hailman et al. 1994). When sampling sentinel behavior, we recorded time of day, height of perch, tree species, and total activity duration.

Foraging behavior and diet. For each foraging event we recorded time of day, capture

technique (which included gleaning, sallying, hanging, hammering, and screening; Remsen and Robinson 1990), substrate, foraging height, and food item. Substrates considered were leaf, fruit, flower, trunk, air and ground (Rosenberg 1990). Foraging height was divided into classes: 0–1 m included the ground, herbaceous vegetation, termite mounds, and litter; 1–4 m included shrubs; and above 4 m included arboreal vegetation.

Reproduction. Only a few birds could be captured and banded during the study. We mapped all nests, active or not. Inactive nests were identified as Curl-crested Jay nests after comparison to active nests and using characteristics such as shape, size, material used, tree species, and height. We measured nest heights on trees, nest diameters and depths, and the diameter of twigs used. All tree species used for nesting were identified. We checked nests with a mirror weekly or once every 15 d to determine activity status. Active nests were monitored every other day to verify number of eggs laid, predation events, hatching dates, and nestling development. We measured length and width of eggs ($N = 8$) and recorded nestling development ($N = 12$) every other day by measuring weight, tarsus length, flat wing length, and bill length from narins. We banded nestlings when they were about 18 d old.

Nest success was measured by the percentage of hatched eggs, of fledglings, and of nests that produced at least one fledgling (Innes and Johnston 1996). Nests were considered depredated when the whole clutch/brood disappeared and when there was no evidence inside or underneath the nest of any other kind of loss. We monitored eight nesting events and observed adult activities with binoculars from a blind 20–40 m away from nests. Behavior recorded included incubating, feeding (food item taken to an incubating adult or nestling), nest-cleaning (removing or eating fecal sacs), and visiting (bird consumed prey item it had taken to nest, or perched on nest). During incubation, we also recorded the time spent inside the nest. In one nest, we used a non-toxic pink ink placed within the nest to mark incubators. Whenever possible, we identified individually marked birds.

RESULTS

The three groups where capturing was attempted had a total of 31 individuals, including fledglings. During 343 h of Tomahawk trapping and 69 h of mist-netting, we captured six individuals (one marked as a nestling), yielding a capture success of 1.2 individuals per 68.7 h of trapping. We also marked eight nestlings, which remained for varying times with their groups. Thus, a total 13 individuals were marked, representing 42% of the birds in the groups.

Home range and group size. We recorded 296 geographical positions (waypoints) for four groups to determine home ranges and breeding areas defended from human intruders. Group sizes were: group A, 9; group E, 11; group I, 10; and group N, 11 individuals. Mean ± SD home range was 172 ± 46 ha. Groups A, E, I, and N used areas of 202 ha ($N = 93$ waypoints), 211 ha ($N = 104$), 167 ha ($N = 63$), and 108 ha ($N = 36$), respectively. Home range overlap occurred between groups A and N (25 ha) and A and E (61 ha; Fig. 1).

We observed extensive movements of the groups during the nonreproductive period from March to July. Because most individuals were not marked, it was impossible to know whether groups moved as units or if individuals left their groups to sojourn in neighboring areas. For instance, individual number 6 from group E was captured on 7 July 2000, sighted three days later 1130 m from the trap, and on 13 July it was seen 2070 m from this latter site (1150 m from the trap). In July we also observed individual movements of at least 1500 m in 1 h 45 min (calculated based on records from five waypoints).

Groups A, E, I, and N defended reproductive areas from human intruders; reproductive areas consisted of 20 ha ($N = 12$), 24 ha ($N = 18$), 31 ha ($N = 15$) and 41 ha ($N = 22$), respectively, with a mean (± SD) of 29 (± 8) ha. The defended breeding areas of groups A, E, and N were in areas of home range overlap (Fig. 1).

Activity patterns. We sampled activities for a total of 41 h divided into three periods: 12 h between 06:00 and 10:00; 21 h between 10:00 and 14:00; and 6 h between 14:00 and 18:00. During the first period of observations, between 06:00 and 10:00, observations were made on an average (± SD) of 4.77 (± 3.27) individuals (ranging from 1 to 12). Observations in the second period, from 10:00 to 14:00, were made on an average (± SD) of 4.37 (± 2.91)

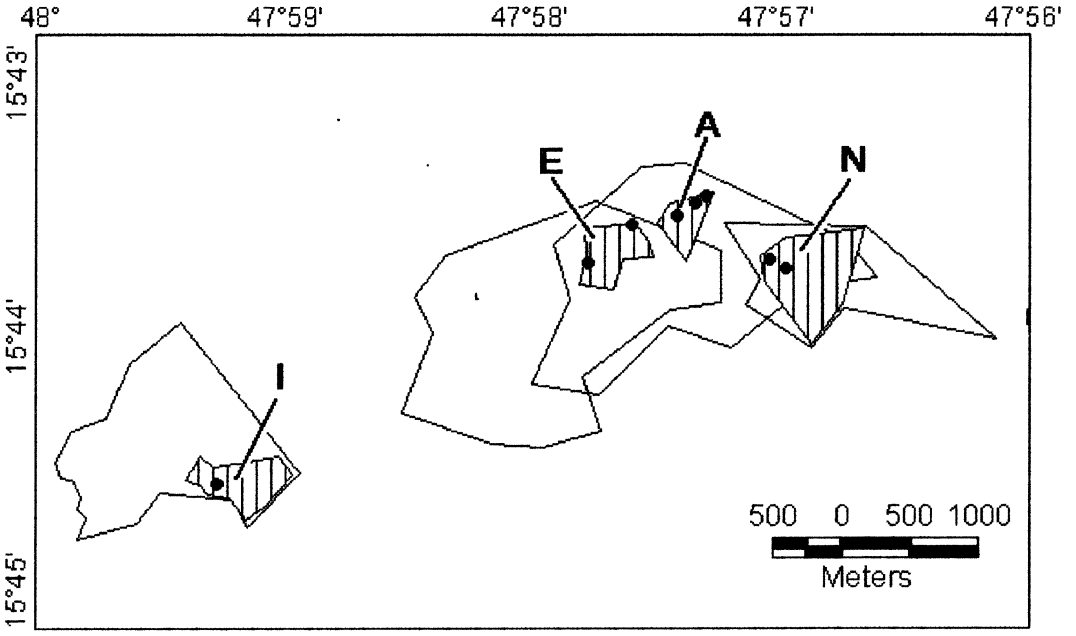

Fig. 1. Home ranges (clear polygons), breeding areas defended from human intruders (shaded polygons), and nest sites (closed circles) for groups I, E, A, and N of Curl-crested Jays in central Brazil in 1999–2000.

birds (ranging from 1 to 13), and for the period from 14:00 to 18:00, 6.14 (± 4.14) birds (ranging from 1 to 14). The duration of observation for each bird varied greatly, ranging from one to 80 continuous min. Frequency of activities varied significantly among the three periods (χ^2_{10} = 147.045, $P < 0.001$; Fig. 2). Sentinel behavior accounted for approximately 50% of the total activity time, and was equally intensive during the three time periods. Although samples were unequal for the time periods, foraging seemed to decrease slightly during mid-day, concurrent with an increase in resting. We recorded a few direct interactions between individuals, and these happened during foraging and preening events.

Time spent in sentinel activity did not differ between dry and wet seasons ($t = -0.561$; $P = 0.614$). Sentinels generally used high perches from where they surveyed their surroundings. Perches used during this activity had a mean (± SD) estimated height of 7.4 (± 2.2) m ($N = 196$). Tree species chosen by birds for perching during sentinel behavior sometimes coincided with those used for nesting (Table 1). The most frequently chosen species, *Dalbergia miscolobium*, however, was never found to harbor nests. Individuals vocalized loudly at the first sign of predators or intruders in their area, leading to grouping of several individuals around the intruder. Several times, we observed two to five individuals mobbing Crested Caracaras (*Polyborus plancus*).

Foraging behavior and diet. We recorded a total of 124 foraging events. In 95 of these, the capture technique was identified: 59% gleaning, 25% sallying, 11% hanging, 8% hammering, and 1% screening. In 101 events we detected the substrate used for the capture: 42% were fruits, 23% leaves, 15% trunks and branches, 10% flowers, 7% soil, and 3% air. The chief vegetation layer used was above 4 m (64% of events), then shrubby vegetation (29%), with only a few observations in the lowest layer (7%). In 84 events we could identify food items: 47% were insects, 40% were fruits, 12% were nectar, and 1% were vertebrates. Among insects we identified only termites and orthopterans. Among fruits consumed, we recorded *Shefflera macrocarpa* ($N = 19$), *Psitacanthus robustus* ($N = 8$), *Caryocar brasiliense* ($N = 3$), *Syagrus flexuosa* ($N = 2$), *Pouteria ramiflora* ($N = 1$) and *Eugenia calycina* ($N = 1$). Fruits from *S. macrocarpa* and *P. robustus* were

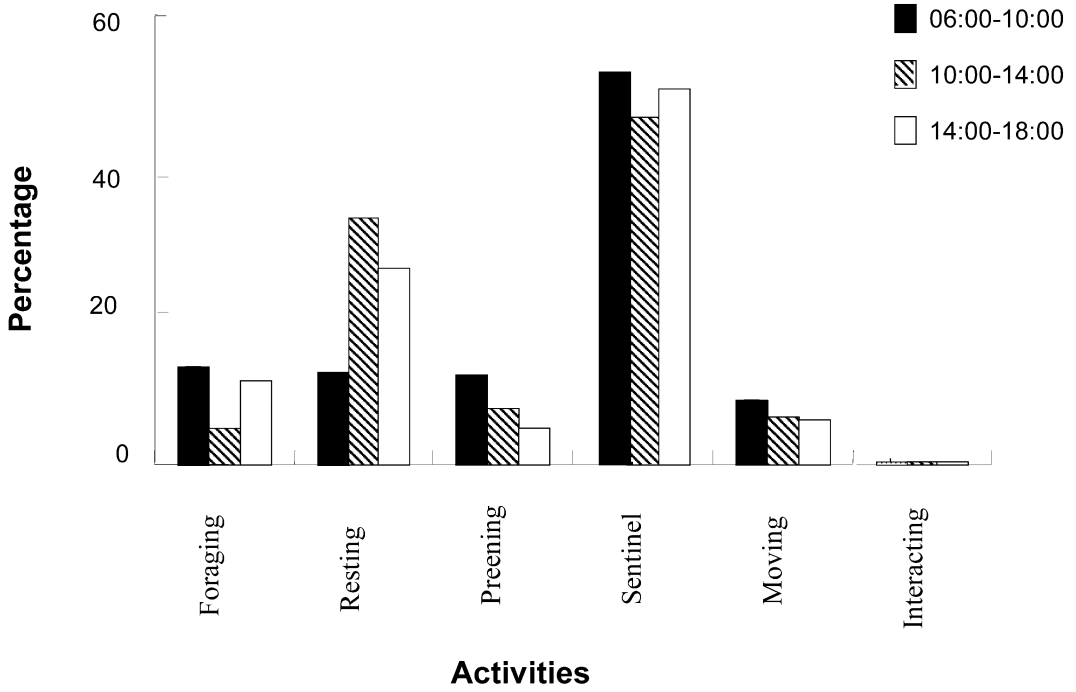

Fig. 2. Temporal patterns of behavioral activities of Curl-crested Jays in central Brazil in 1999–2000.

usually swallowed whole, while larger fruits, such as those from *C. brasiliense* and *S. flexuosa*, were carried from perch to perch and were manipulated and eaten in parts.

Reproduction. We found eight active and 10 inactive nests that were identified as Curl-crested Jay nests. All of them were located in cerrado areas. Nests were cup shaped, built with twigs, and lined with thin vegetational material such as lianas and roots. The 16 nests measured were found in eight tree species (Table 1) and were located between 2.7–6.6 m high (4.7 ± 1.0). Mean (± SD) external diameter was 47.4 (± 8.6) cm, mean (± SD) cup depth was 15.4 (± 2.5) cm (N = 14 nests) and mean (± SD) twig diameter was 0.7 (± 0.2) cm (N = 150 twigs). Mean (± SD) diameter of the egg chamber was 15.8 (± 1.1) cm and mean (± SD) depth 6.5 (± 1.2) cm (N = 14 nests). Eggs were pale blue-green with brownish spots with a mean (± SD) length of 33.9 (± 1.0) mm and a mean (± SD) width of 24.1 (± 0.5) mm (N = 8).

Table 1. Use of cerrado tree species by the Curl-crested Jay for nesting and sentinel behavior in central Brazil in 1999–2000.

Tree species	Nesting N (%)	Sentinel behavior N (%)
Aspidosperma tomentosum	1 (5.5)	—
Caryocar brasiliense	11 (61)	5 (3)
Dalbergia miscolobium	—	50 (28)
Dimorphandra mollis	1 (5.5)	6 (3)
Pterodon pubescens	1 (5.5)	3 (2)
Qualea grandiflora	1 (5.5)	25 (14)
Q. parviflora	—	18 (10)
Schefflera macrocarpa	1 (5.5)	21 (12)
Sclerolobium paniculatum	—	12 (7)
Styrax ferrugineus	1 (5.5)	1 (1)
Vochysia tyrsoidea	1 (5.5)	8 (5)
Other	—	27 (15)
Total	18 (100)	176 (100)

The reproductive season started in September in both years, when we found nests that had been recently built or were being built and only with eggs. In 1999 we found two active nests in September, one on 17 September in the laying stage and another on 27 September during incubation. In 2000 we found three

Table 2. Reproductive characteristics of the Curl-crested Jay in central Brazil. Breeding area refers to the area around the nest actively defended against human intruders during the reproductive season. Depredated nests refer to complete elimination of either eggs or chicks. The disappearance of some eggs/nestlings could not be attributed to predation.

Nests	Date	Eggs laid	Eggs hatched	Fledglings	Nest fate	Group size	Breeding area (ha)
N-1	September/1999	5	0	0	Deserted	11	41
N-2	September/2000	6	5	4	Successful	11	41
A-1	September/1999	6	3	3	Successful	9	20
A-2	September/2000	6	4	0	Depredated	9	20
A-3	October/2000	5	0	0	Depredated	9	20
I-1	September/2000	6	2	0	Depredated	10	31
E-1	September/2000	6	0	0	Depredated	11	24
E-2	October/2000	?	4	0	Depredated	11	24
Average (range)		5.7 (5–6)	2.3 (0–5)	0.86 (0–4)		10.4 (9–11)	29 (20–41)

nests in construction on 5 and 12 September, and eggs were laid in these between 6–14 September. Thus, the beginning of reproductive activity coincides with the onset of the first rains of the wet season. No nests were found after March in both years, but on 6 and 14 March 2000 we saw fledglings of one group. In 2000 we found four nests that were the first broods of the season (one from each group) and two nests that were second broods from these same groups that had their first brood depredated. First brood nests were found in September, and second nests were found in October. Both first and second nestings (for those groups that failed) coincided closely in their timing.

Mean (± SD) clutch size was 5.7 (± 0.5) eggs ($N = 7$), and nesting success was low (Table 2). Only two of the eight nests produced surviving fledglings, as five (63%) of the nests suffered predation and one (13%) was deserted. Of the 40 eggs laid, 11 were taken by predators and five were deserted. Of the remaining 24 eggs, 14 (58%) hatched, and of these, 50% fledged. Predation occurred during incubation ($N = 2$), when nestlings were recently hatched ($N = 1$), and when nestlings were about 16 d old ($N = 2$). Besides predation, one nestling death occurred during the third week of life, probably due to sibling competition for food, as it was much smaller and had four larger siblings.

Potential predators seen around the nests were one Yellow-headed Caracara (*Milvago chimachima*), five Crested Caracaras, and, once the presence of four jays mobbing close to the ground suggested the presence of a terrestrial predator, possibly a snake. Other potential predators sighted in the study area were Roadside Hawks (*Rupornis magnirostris*), Savanna Hawks (*Buteogallus meridionalis*), and marmosets (*Callithrix penicillata*). During the reproductive period, the most common behavior of the jays after detecting a predator was the emission of a short alarm call at a distance from the predator and then remaining quiet and hidden among branches and leaves. The jays became intolerant and aggressive to us following predation events.

During the reproductive season of 2000, we made focal observations of eight nesting events, totaling 104 h (24 h during incubation and 80 h after hatching). As most of the birds were not banded, it was impossible to identify all adults that visited nests, but we verified in one nest that at least four individuals fed nestlings, since they were simultaneously bringing food to the nest. We also identified, in another nest, at least six individuals that communicated sporadically with others that were farther away.

The possible range in incubation period is from 18–20 d (based on observations in three nests), calculated from the date of clutch completion until the hatching of the first egg. In one nest we marked the incubating bird with a pink, non-toxic ink left inside the nest, and verified that this bird incubated eggs during nine periods of observation (periods ranged from 60 to 180 min). The mean uninterrupted time of incubation by a single bird was 94 min ($N = 9$, ranging from 39–167 min). The incubator emitted calls similar to hiccups, and a few seconds before an individual arrived with food, the

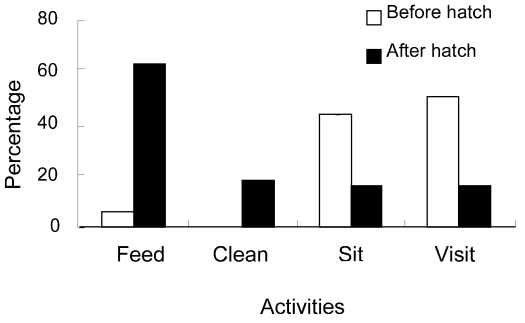

Fig. 3. Behavioral activities of adults prior to and after hatching of chicks in Curl-crested Jays in central Brazil.

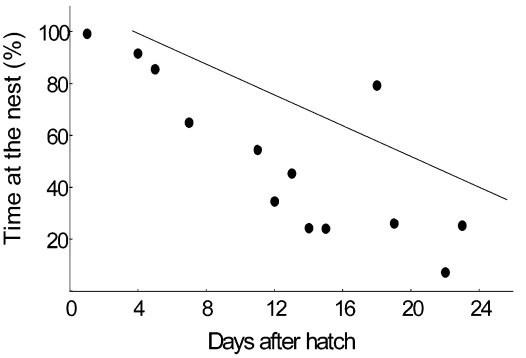

Fig. 4. Association between percentage of time that adults spent at the nest and nestling age ($r_s = 0.80$, $P < 0.001$) in Curl-crested Jays in central Brazil.

bird at the nest increased the frequency of calls and opened its wings. Before a foraging event, other individuals also gave this hiccup call, even if outside the nest. During incubation, we observed 89 arrivals at the nest: 50% were visits, 44% were to incubate, and 6% were to feed the incubator. We observed that two to four eggs hatched in an interval of two days. After hatching, we observed 773 arrivals at the nest: 69% to feed the brooding bird and/or hatchlings, 18% to clean the nest, 16% to incubate (brood) nestlings, and 16% were visits (Fig. 3). Nest cleaning consisted of taking away fecal sacs, ants, and probably other arthropods, which were usually ingested.

After hatching, we observed more than one individual brooding for long periods, unlike during the incubation period. During the first week after hatching, adults almost never left the nest alone; usually there were two or more adults present at the nest. Time spent by adults at the nests was negatively correlated with nestling age ($r_s = -0.797$, $P < 0.001$, $N = 13$; Fig. 4).

Frequency of visits to feed nestlings at nests N-2, I-1 and E-2 were recorded during 36, 23 and 12 h of observation, respectively. Parental care behavior was affected by the presence of the observer. The low frequency of approaches to the nest at 06:00, 09:00, 12:00 and 15:00 h coincided with the arrival of observers. During the first week after hatching, adults brought food and shared it with the bird that was at the nest, and both of them distributed it among nestlings. When adults hesitated to approach the nest, the incubator left the nest to receive the food. The frequency of feedings per nestling was almost constant during the day, being slightly higher at the beginning and end of the day. Food was regurgitated to nestlings, so it was difficult to identify food items or their size. Nestlings begged vigorously for food, but we never recorded any aggressive interactions among them. Nestlings hatched at 11.3 (± 2.5) g ($N = 4$) and fledged after about 24 d at 207.5 (± 3.5) g ($N = 2$).

DISCUSSION

The average home range of 172 ha for the Curl-crested Jay is large in comparison to other *Cyanocorax* species from South America: 20–30 ha for the Plush-crested Jay (*C. chrysops*; Uejima 1998) and 54 ha for the Green Jay (*C. yncas*; Alvarez 1975). This may be a habitat-related difference, since both of these species inhabit forests, while the Curl-crested Jay is endemic to savanna habitats. The high forest vegetation allows individuals to use resources that are vertically distributed; thus, a three-dimensional volume measure would be a more realistic method of describing home range among these species. Additionally, in open vegetation such as in the cerrado biome, individuals of a group can space themselves farther apart while still maintaining effective visual and auditory communication, allowing the group to explore a larger area. Home range can also be related to the availability and density of resources. Groups that live in a high quality environment can use smaller areas compared to groups of the same size inhabiting lower quality areas (Shank

1986). Resource abundance in the savanna is possibly more restricted than in forested areas.

Although we found an overlap in home ranges of different groups, we did not observe interactions between neighboring groups. Often, species that utilize large areas allow the entry of conspecifics from other groups, even for foraging (Goodwin 1986). This might have been the case for individual number 6 that we spotted with a neighboring group in one occasion. Uejima (1998) observed friendly meetings between individuals from different groups of Plush-crested Jays during the nonreproductive period, but according to Goodwin (1986), this tolerance of intruders may decrease as the reproductive period approaches.

Hardy (1969) observed Curl-crested Jay groups in July in central Brazil and proposed that they are nomadic during the nonreproductive period. Our study, however, shows that despite the extensive movements of individuals, the four groups occupied the same areas yearround, indicating that they are sedentary even during the nonreproductive period. It is possible that lone unmarked individuals occasionally sighted at considerable distances from any known home ranges represented floaters in the population, as has been reported for White-throated Magpie-Jays (*Calocitta formosa*; Langen 1996b). Most behavioral studies of corvids have shown them to be territorial during the breeding season (Goodwin 1986), and this appears to be true for the Curl-crested Jay. Although we did not find true breeding territories (areas defended from conspecifics), the defensive behavior around the nest suggests a well-defined area actively defended against possible predators and probably against other jays. Our study suggests that although these jays have extensive home ranges, they also have well-defined breeding territories that are much smaller.

The varied diet of Curl-crested Jays implies that they are opportunistic birds that make use of any seasonally abundant or available resource. The high fruit consumption by these jays (39.8% of all items), associated with their movement of great distances, suggests that this species may be an important seed-disperser for the cerrado. In addition to its varied diet, this jay also used at least seven different techniques for food acquisition, several substrates, and all of the vegetation layers, indicating great flexibility in exploring resources. Many jays worldwide harvest and cache acorns or seeds. This behavior was not observed in the Curl-crested Jay. However, we did observe one adult consuming a *C. brasiliense* fruit, then left the seed on a tree fork, flew off for a few minutes, then returned to finish eating the seed.

Despite its endemic status in the cerrado, a biome which is suffering drastic alterations, the Curl-crested Jay is still a common and nonthreatened species. Like other corvids, it can use disturbed habitats such as pastures, orchards, and cropland, as long as these contain some areas with trees. Despite this adaptability, the species does not inhabit urbanized areas.

Groups started their reproductive activity at the start of the rainy season. They exhibited a strong preference for nesting in *C. brasiliense* trees, a common species in the cerrado, which was also used by the birds as a source of nectar and fruits. Courtship behavior may include males feeding females through regurgitation, as we observed two adults doing this, which is a common trait in corvids (Goodwin 1986). The date of first laying may affect reproductive success, because it determines the number of nesting events possible during the reproductive period (Innes and Johnston 1996). Nests found in the beginning of the reproductive period, and our observation of fledglings in March 2000, suggest that groups repeatedly produce nests in each reproductive season, similar to other corvids (Brown 1963; Hardy et al. 1981; Langen and Vehrencamp 1999). Large group sizes also favor more than one nest per season, because several individuals care for fledglings while the reproductive pairs can resume breeding more promptly, as in the White-throated Magpie-Jay (Langen 1996b).

The frequent occurrence of sentinels and the strong alarm vocalizations suggest a high predation pressure, and the nest predation seen in our study supports this conjecture. Predation was the chief cause of clutch loss. In the Florida Scrub Jay (*Aphelocoma coerulescens*) predation is also the main cause of nest loss, with only one in four eggs fledging and only one in 13 eggs ever producing a bird to reproductive age (Fitzpatrick and Woolfenden 1984; Woolfenden and Fitzpatrick 1986). For the Curl-crested Jay the loss of eggs was even greater, with only one in six eggs surviving to fledging. During hatching some eggs disappeared, probably removed or eaten by parents.

Because clutch size was between five and six eggs in all nests, and assuming that when multiple females lay eggs in a joint nest clutch size is more variable, we infer that only one female laid eggs in each nest. The two nests with five eggs were depredated and may have been cases of incomplete clutches. Six eggs is probably the typical clutch size for the Curl-crested Jay. However, a clutch size of six is larger than the few descriptions available for clutch size in other *Cyanocorax* jays. In the cooperative Azure Jay (*C. caeruleus*), two successful nests contained four eggs each (Anjos 1995). In the Green Jay studied by Alvarez (1975) in Colombia, three nests had clutches of four eggs. The maximum number of eggs seen in the Plush-crested Jay also was four eggs. While our observations indicated that only one individual was responsible for incubation duties (with short substitutions), it was clear that several group members contributed to feeding of chicks. This leads us to suggest that the Curl-crested Jay is a cooperative breeder. However, further evidence (e.g., genetic analyses of relatedness among nestmates) is needed to exclude the possibility that more than one female is laying eggs in nests.

In cooperative breeding systems, helpers care for nestlings that are not their own offspring but are usually siblings, meaning helpers gain some indirect fitness benefits (Skutch 1961; Selander 1964; Brown 1969, 1974, 1987). Helpers have the advantage of living under their parent's protection while gaining experience that may increase their status and dominance (Woolfenden 1975; Emlen 1982). In South American corvids of the *Cyanocorax* genus, cooperative breeding has been reported for the Beechey Jay (*C. beecheii*; Brown 1987), the Tufted Jay (*C. dickeyi*; Brown 1987), the Green Jay (Alvarez 1975), the Azure Jay (Anjos 1995) and the Plush-crested Jay (Uejima 1998). Communal breeding, where more than one female in the unit is reproductively active (Brown 1987), has also been reported for a few *Cyanocorax* species, including the Bushy-crested Jay (*C. melanocyanea*), the San Blas Jay (*C. sanblasiana*) and the Yucatan Jay (*C. yucatanica*; Brown 1987). None of these communal breeders, however, are known to be joint nesters, that is, where two or more females use the same nest for laying their eggs.

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