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Nest Architecture, Clutch Size, Nestling Growth Patterns and Nestling Attendance of the Fire-eyed Diucon (*Xolmis pyrope*) in North-Central Chile

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ABSTRACT.—We present descriptions of nest architecture, clutch size, nestling growth and nestling attendance for the Fire-eyed Diucon (*Xolmis pyrope*), based on nests found at the Fray Jorge National Park, Chile, at the northernmost part of its distribution. Nests were cup-shaped structures averaging 283.5 ± 26.6 mm in width and 123.1 ± 6.8 mm in height ($n = 5$), found in matorral steppe habitat and Olivillo humid forest relicts. Nests contained 2–3 eggs. Nestling growth in Fray Jorge's nests was nearly two times slower than in populations from central Chile, as suggested by our calculations of the constant rate ($K = 0.277$) and the T_{10-90} period (12.9). During 20 hrs of video recording, the breeding adults spent a total of 3.4 hrs at the nest. Both parents attended the nest, and the rates of visits, nestling provisioning and fecal sac removal increased with nestling development. We observed that adults can still care for the young at least 2 weeks after fledging, covering an area of 2.3 ha while searching for food. This information could be valuable for further studies on geographic variation in the species' behavioral ecology. Received 6 April 2015. Accepted 17 September 2015.

Key words: egg size, incubation period, nesting ecology, nestling growth, parental care, population variation.

The Fire-eyed Diucon (*Xolmis pyrope*) is a medium-size tyrannid that breeds from north-central Chile (Coquimbo Region, 30° S) and west-Argentina (Neuquén Province, 38° S) to Tierra del Fuego and Isla Navarino (Magallanes and Chilean Antarctica Region, 55° S) (Jaramillo 2003). Very little is known about the breeding ecology of the

eight species of *Xolmis* (Fitzpatrick et al. 2004; but see Mezquida 2002, de la Peña 2005), which is mostly limited to brief descriptions of their nests and eggs (Heming et al. 2013). However, recently Marín (2013) compiled all available information on the natural history of the Fire-eyed Diucon in central Chile, providing new and thorough descriptions of its breeding phenology, the duration of incubation and nestling period, and patterns of nestling growth, based on 33 nests.

Although the breeding ecology of the Fire-eyed Diucon is now much better known, the available information is geographically limited, since most studies have been localized in the south-central part of its distribution, mainly between 33–38° S (for a review see Marín 2013). Additional data from other localities are needed to make inter-population comparisons throughout the species distribution, which will be essential to determine if breeding patterns vary geographically (see Heming et al. 2013). Here, we provide complementary information from the northernmost part of the distribution of the Fire-eyed Diucon, including (i) description of nest architecture and materials used for nest construction, (ii) duration of incubation and nestling periods, (iii) estimation of some nestling growth parameters, (iv) descriptions of nestling attendance and its phenological variation, and (v) notes on parental care after fledging.

METHODS

Our observations were conducted in Fray Jorge National Park (30° 38' S, 71° 40' W; see Quirici et al. 2014, Kelt et al. in press), located in the

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Coquimbo Region in north-central Chile. Fray Jorge has a predominantly semiarid landscape dominated by matorral steppe (Luebert and Pliscoff 2006, Chester 2008), with Olivillo (*Aextoxicon punctatum*) humid forest relicts at the top of the coastal mountain range (Villagrán et al. 2004).

Nest description was standardized by following methods and categories described by Hansell (2000). In addition to the clutch size and egg descriptions, we measured tarsus length, bill length, wing chord, and body mass for each nestling from days 3–19 every other day using an electronic caliper (0.01 mm) and a digital scale (0.01 g). A logistic model was fitted to the body mass data in R 2.15.2 (R Core Team 2012), in order to calculate the rate constant K and the time interval for growth from 10–90% (T_{10-90} ; Ricklefs 1967). Nestling attendance was described with a partially concealed video camera placed at 5–6 m from the nest (Greeney et al. 2005, Hannelly and Greeney 2008). The nest was video recorded at all nestling stages until fledging, recording 1 hr/day during 20 days starting 1 hr after sunrise (between 0744–0757 Chile Standard Time, CLT). Nestlings were color banded, allowing us to identify them for 2 weeks after fledging to describe parental behavior, undertaking two behavioral observations per day, 1 hr after/before sunrise/sunset. Family movements were estimated by recording each observation point with a GPS with a 3-m error, and then measuring areas with ArcGIS 9.3 (ESRI 2008) by using a 100% Minimum Convex Polygon.

RESULTS AND DISCUSSION

We opportunistically found nests at different stages of the breeding season during November 2013 ($n = 2$) and October–November 2014 ($n = 3$). Both nests from 2013 were found during or shortly after fledging. The three nests from 2014 were found during the egg laying ($n = 2$) or nestling periods ($n = 1$). Descriptions of nesting habitat and nest measurements were based on all nests ($n = 5$), but determination of nest architecture and composition of nesting materials were based only on the three nests found during 2014, since they were fresh and complete when collected. Egg description and determination of nestling growth patterns were based on the two nests from 2014 that were found during egg laying, while we followed one of these nests to describe nestling attendance and parental care.

Breeding Period.—All five nests were found between October–November, and the stage at which they were found suggests that breeding activity began during the first 2 weeks of October, similar to the timing of central populations, despite being at the species northern limit (Goodall et al. 1957, Marín 2013; Table 1). We did not find late nests, indicative of second or further breeding attempts, but judging by the vocal activity of breeding adults, it seems the breeding period at Fray Jorge could last until December, as found elsewhere (Marín 2013).

Nest Description and Location.—The two nests from 2013 and two nests from 2014 were all found in matorral steppe (214 m altitude), whereas one nest from 2014 was located in a clearing within an Olivillo forest patch along the coastal mountain range (502 m). All nests were placed at an average height of 103 cm above ground ($SD = 43$, $n = 5$) and at 33 cm from the external branches/border of the plant used as the nesting site ($SD = 29$). Three out of four matorral nests were located in small bushes of *Senna cumingii*, while the fourth nest was on an *Echinopsis* cactus. The forest nest was near the center of a *Raphitamus spinosus* tree, being placed considerably higher than the others (at 162 cm above ground). Nest attachment in all cases was bottom-multiple (sensu Hansell 2000), where one to two branches gave lateral support while two or more horizontal branches held the nest from below.

All nests were cup-shaped and their mean \pm SD external measurements were 283.5 ± 26.6 mm in width and 123.1 ± 6.8 mm in height ($n = 5$). The egg cup measurements averaged 80.6 ± 3.9 mm wide \times 42.6 ± 2.1 mm deep, while the outer rim width ranged from 15.4–73.2 mm. Mean nest weight was 148.5 ± 6.6 g. Variation in measurements of the forest nest was within the range of variation of matorral nests (data not shown). There are few external measurements to compare with, but cup dimensions were similar to the nests studied in central Chile (Marín 2013; Table 1), while smaller than those reported for two nests from southern Chile and Argentina (Vuilleumier 1994, Fitzpatrick et al. 2004; Table 1).

The presence of a structural layer and internal lining and the absence of attaching materials were shared features among the five nests. Structural layers were composed of sticks and twigs from 4–7 species, with *Proustia pungens*, *Adesmia bedwelli*, *Gutierrezia resinosa*, and *Haplopappus* sp.

TABLE 1. Comparison of breeding parameters between different populations within the geographical range of the Fire-eyed Diucon (*Xolmis pyrope*).

Parameter	Northern population (Fray Jorge)	Central populations ^a	Locality (reference) ^c
Breeding season	October–December	September–December November–January	C. Chile (Marín 2013) S. Chile (Goodall et al. 1957)
Nest cup dimensions (mm)	80.6 × 42	78.5 × 51 100 × 50 190	C. Chile (Marín 2013) S. Chile (Vuilleumier 1994) S. Argentina (Fitzpatrick et al. 2004)
Incubation period	18 days	17–19 days	C. Chile (Marín 2013)
Hatching asynchrony	Differences of a few hours	Up to a day (clutches > 3 eggs)	C. Chile (Marín 2013)
Nestling period	20–21 days	13–15 days	C. Chile (Marín 2013)
K/T_{10-90}^b	0.227/12.9 days	0.602/7.3 days	C. Chile (Marín 2013)
Max. weight (g)	26.6	31.8	C. Chile (Marín 2013)
Max. tarsus/bill length (mm)	25.0/12.0	26.4/12.0	C. Chile (Marín 2013)
Max. wing chord (mm)	65.0	67.0	C. Chile (Marín 2013)

^a Populations located farther south than the Fray Jorge National Park (north-central Chile) are referred to here as central populations.

^b K : constant growth rate; T_{10-90} : time interval for growth from 10–90% (see Ricklefs 1967).

^c C.: Central; S.: Southern.

being the most used in matorral nests; *Baccharis* sp., *Azara microphylla* and *Fuchsia* sp. were the most abundant in the forest nest. The majority of sticks showed the presence of three lichen species: *Usnea pusilla*, *Usnea rubicunda*, and *Xanthoria* sp. The structural layer made 84–92% (122–135 g) of the total dry mass of the matorral nests, but only 50% (79 g) of the forest nest. Internal linings were commonly made of rootlets and plant down, a few feathers and human or animal hair (horse and goat). Feathers were more common in the forest nest. This layer represented 7–9% (8–12 g) of the dry mass of matorral nests, and nearly 28% (44 g) of the forest nest.

Only the forest nest and one of the matorral nests showed an external lining (sensu Hansell 2000). The external lining of the forest nest was a voluminous layer made of moss and fresh greenery, covering the entire rim and being 22% (35 g) of the nest total dry mass. The external lining of the matorral nest was a faint structure, composed of lichens and mosses, only representing 0.2% (0.2 g) of the total mass. Both Marín (2013) and Vuilleumier (1994) described their nests as bulky cups of sticks abundantly covered by moss or lichens, which could confer some mimetic features to the structure. Only the forest nest matched this description, while the remaining four, all located in matorral steppe, virtually lacked the mossy external lining. The lack of external linings could be a consequence of (i) the absence of such items in the matorral habitat, and/

or (ii) the lack of need for this material for insulation or mimicking purposes, since mosses could be more effective in the greener, colder and more humid micro-environment inside the Olivillo forest patches (Villagrán et al. 2004). This local variation could suggest that differences among the architecture and composition of Fray Jorge's nests and those described from other localities could be a consequence of the local availability of materials (Hansell 2000), rather than inter-population differences.

Eggs and Incubation Periods.—We found only two nests during the egg-laying stage in the matorral habitat. The forest nest had two chicks when discovered, but 5 days later they were found dead with no signs of physical trauma. As the clutch sizes described for central Chile (Goodall et al. 1957), the two nests contained 2 and 3 eggs. Similar to the description and linear measurements recorded by Marín (2013), eggs were mostly white and some showed small reddish spots, averaging 24.3 ± 0.2 mm long \times 18.4 ± 0.2 mm wide ($n = 5$). We could not determine if one or both parents were involved in incubation, but it is likely that only the female incubated the eggs, as is typical for many flycatchers (Fitzpatrick et al. 2004, Marín 2013).

Incubation started once all eggs were laid and lasted 18 days in both nests, similarly to populations from central Chile (Table 1). Hatching was almost synchronous, with the third egg of the first nest hatching a few hours later than the

other two. However, Marín (2013) indicated that incubation starts after the second egg is laid, causing hatching asynchrony in those nests with clutch sizes ≥ 3 eggs (Table 1). Our sample size is too small to make any reliable comparison, but this variation in hatching synchrony/asynchrony could reflect shorter periods between egg laying in Fray Jorge. This requires further study.

Nestling Growth.—Nestlings opened their eyes 10–11 days after hatching, 3 days later than in central populations (Marín 2013). Nestlings reached a maximum mass that ranged from 24.8–26.6 g ($n = 5$), ca. 78–84% of the mean maximum body mass gained by chicks from central Chile and ca. 67–72% of the weight of a typical adult (37 g; Marín 2013); this maximum gain occurred during the 16th day of the nestling period, taking 3 additional days than the time described by Marín (2013). We obtained similar values to those described in central Chile for the remaining measurements of nestling growth (Table 1): wing chord reached a maximum length of 65.1 mm, while maximum bill and tarsus lengths reached 12 mm and 25 mm, which corresponded to the 59% (110 mm), 78% (15.4 mm), and 95% (26.4 mm) of adult measurements, respectively (Marín 2013). However, these maximum values were attained between days 17–19, taking 3–7 additional days than the time reported for central populations (see Marín 2013).

According to our calculations of the constant rate ($K = 0.277$) and the T_{10-90} period (12.9), nestling growth in Fray Jorge's nests was nearly two times slower than in central populations (Table 1) but resembled some values reported for Neotropical flycatchers of comparable size like the Streaked Flycatcher (*Myiodynastes maculatus*, $T_{10-90} = 11.4$) and the Tropical Kingbird (*Tyrannus melancholicus*, $T_{10-90} = 15.8$; Starck and Ricklefs 1998). In accordance with the lower growth rate, the nestling period lasted 20–21 days for both nests, 28–38% longer than that reported for central Chile populations (Table 1). This was also longer than the observed nestling periods of some congeners, such as the Black-crowned Monjita (*Xolmis coronatus*; 14 days) (Mezquida 2002), and even the White Monjita (*Xolmis irupero*; 17–18 days) (de la Peña 2005), which is a cavity nester.

Our findings fit within the pattern of a lower growth rate closer to the equator (Ricklefs 1976), given the resemblance between our calculation of the time interval for growth and those estimated for some Neotropical flycatchers, meaning that growth

rates could be lower in northern populations of the Fire-eyed Diucon. However, our reduced sample size is inconclusive and we cannot rule out other potential explanations for the results, such as local effects causing retarded development (sensu Ricklefs 1968). For example, atypical rainfall amounts and low productivity during a breeding season can negatively impact growth rates, as it seems to have occurred in Fray Jorge during the last few years (CEAZA 2012; Quirici et al. 2014). A systematic study of the species' breeding ecology in the mid-term will be essential to confirm the main factor generating the observed patterns.

Nestling Attendance and Parental Behavior.—We followed one matorral nest containing three nestlings, where biparental care was evident, as in other tyrannids (Fitzpatrick et al. 2004). Although we cannot confirm which sex was more involved in parental duties, it is likely that the female did all the brooding as in other flycatcher species (Llambías and Ferretti 2003, Greeney et al. 2005, Hannelly and Greeney 2008, Hoffmann et al. 2009). One of the parents stayed the night between days 2–17, arriving at the nest after sunset between 2110–2200 CLT, and departing shortly after sunrise. Brooding bouts occurred only between days 2–6, and their frequency and duration decreased over time (data not shown), as reported for the Smoky Bush-Tyrant (*Myiotheretes fumigatus*; Stawarczyk et al. 2012). Episodes of 'team feeding' were mostly observed during brooding bouts, with one of the parents transferring the food to the brooding mate, which subsequently fed the three nestlings (Fiorini and Rabuffetti 2003, Hannelly and Greeney 2008). There were few episodes of 'team feeding' after the 7th day, as well as some cases of simultaneous feeding (see Pizo et al. 2010).

The breeding adults spent a total of 3.4 hrs at the nest during 20 hrs of videotaping, corresponding to the 17% of total time recorded. The daily total time at the nest per recording hour ranged from 1.3–41.4 mins (2–69% of daily recording time) and averaged 10.7 mins (SD = 12.7, $n = 20$), showing a sharp decrease between days 2–7, and then stabilizing below 10 mins after this period (Fig. 1A). The mean duration of daily nest visits per recording hour was 1.7 mins (SD = 2.4), although most of them lasted less than 6 secs after the 8th day. We also recorded a decreasing trend in the duration of such visits (Fig. 1B). These decreases can be explained, at least in part, by the reduction of brooding times and frequency during

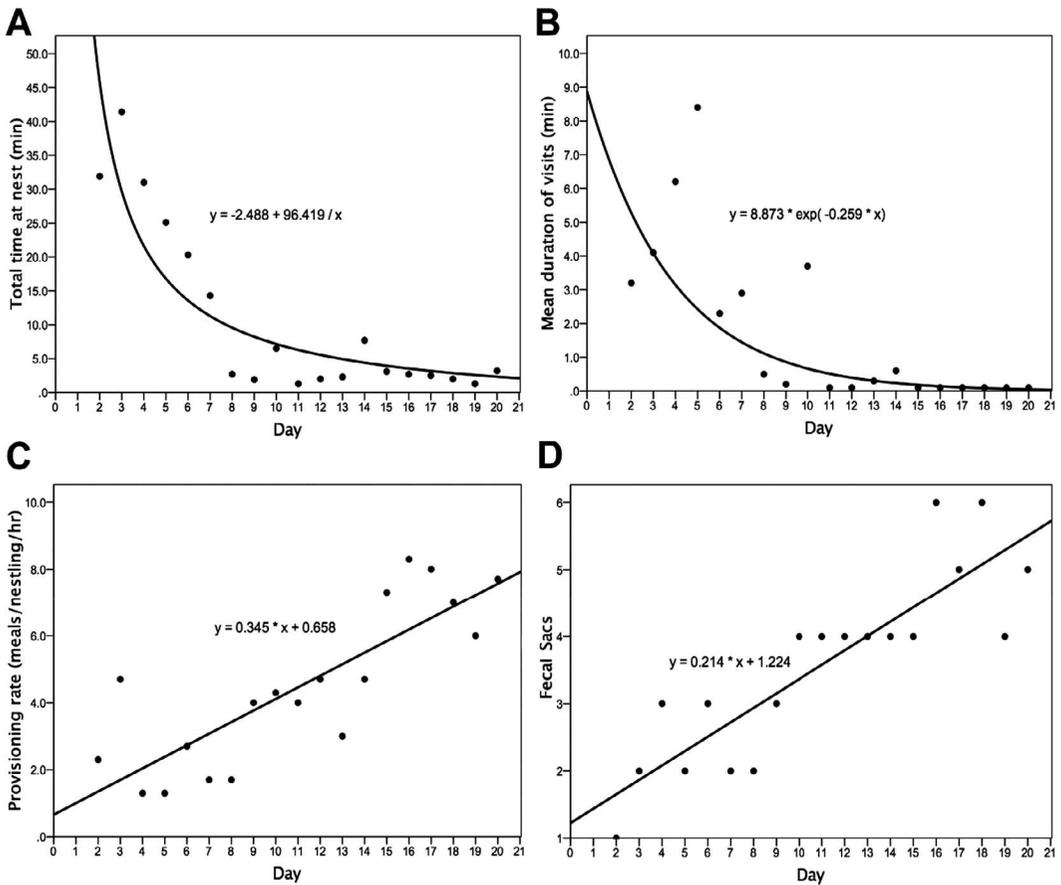


FIG. 1. Temporal variation in nest attendance activities by a breeding pair of the Fire-eyed Diucon (*Xolmis pyrope*) during the nestling period at Fray Jorge National Park, north-central Chile. All plots include the model fit for each case: (A) inverse, (B) exponential, and (C) and (D) linear. All models were highly significant (all $r^2 > 0.7$, all $P < 0.001$). All values correspond to daily times/rates of nest attendance during one recording hour throughout 20 days.

nestling development (Hannelly and Greeney 2008, Stawarczyk et al. 2012).

A rising trend was observed for visiting and provisioning rates (No. per hr/nestling), both showing evident increases during days 9–14 (compared with days 2–8) and days 15–20 (compared with days 9–14) (Fig. 1C). Daily fecal sac removal rates averaged 4 sacs/hr (SD = 1.4, range = 1.1–6.0, $n = 20$), also tending to increase with nestling growth (Fig. 1D). The adults swallowed the fecal sacs until the 7th day but started to remove them from the nest afterwards (but see Greeney et al. 2005). When grouping nestling days in three periods according to the attendance rates (early growth: 2nd–8th; mid: 9th–14th; late: 15th–20th), we observed significant differences in mean provisioning (ANOVA, $F_{2,16} = 49.1$, $P < 0.001$) and fecal sac removal

rates (ANOVA, $F_{2,16} = 28.1$, $P < 0.001$) between periods. Post-hoc tests confirmed that all periods were different from one another (Tukey's DHS, all $P < 0.02$). The estimated attendance rates were similar to the values reported for some tyrannid species of similar size. Llambías and Ferretti (2003) described a provisioning rate of 7.8–9.4 trips/hr for the Great Kiskadee (*Pitangus sulphuratus*) in Argentina, which would be similar to the rates we calculated for the nestlings' late growth stage (days 15–20, Fig. 1C). Unfortunately, the authors did not report the brood sizes in their study, and therefore, it is not clear if these rates corresponded to the whole nest or to each nestling. In contrast, Stawarczyk et al. (2012) estimated 4.0 and 4.3 meals/hr/nestling during the second and third weeks of nestling development for the Smoky Bush-Tyrant in Ecuador, resembling

the values we obtained for the nestlings' mid growth stage (days 9–14, Fig. 1C). This comparison should be taken cautiously, however, since attendance rates for the Fire-eyed Diucon (this study) and the Smoky Bush-Tyrant (Stawarczyk et al. 2012) were based on just one nest, thus requiring further research to confirm if the reported values hold.

The chicks fledged during the 21st day at noon (between 1920–1930 CLT) and joined their parents in a small bush near the nest. The family remained quiet during the night inside the bush. From the next morning and through the following 2 weeks, we were able to locate just one adult with one fledgling. We could not determine if the family split into two groups or if the missing birds were predated during the first night. We obtained 22 foraging observations while tracking the family. The adult was observed foraging for ground invertebrates in ~70% of all observations, then flying to a higher perch where the begging fledgling awaited. According to the location of the foraging sites, the family was displacing at an average linear distance of 83.5 m/day (SD = 54.8, $n = 22$) from their nest. By generating a minimum convex polygon with all the foraging sites (100% MCP), we estimated that the family covered 2.3 ha during the first 2 weeks after fledging. We could not locate the birds after this period.

Despite our reduced sample size, we added new and detailed information on the nest architecture, nestling attendance, and breeding ecology of the Fire-eyed Diucon, which could be valuable for further studies on geographic variation in the species' behavioral ecology. Such studies should encourage ornithologists to carefully gather data on nesting habits and breeding ecology from different localities within a species breeding range. This information could uncover the presence of geographical variation in behavior and other phenotypic traits (e.g., Martin et al. 2007, Jetz et al. 2008, Heming & Marini 2015) to help understand the relationship between life history patterns and ecological variation among populations.

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Consumption of Müllerian Bodies by Golden-olive Woodpecker (*Colaptes rubiginosus*) in Nicaragua's Highlands

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ABSTRACT.—The Golden-olive Woodpecker is a generalist species found in a wide range of habitats, being particularly common in coffee plantations within Nicaraguan cloud forests. Observations of an individual

feeding at the base of Cecropia leaves revealed it was consuming Müllerian bodies that the Cecropia produces to feed Azteca ants as part of a host-inhabitant mutualistic symbiosis. This record further documents the plasticity of some species as they search for alternative sources of energy. *Received 4 February 2015. Accepted 24 July 2015.*

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INTRODUCTION

Woodpeckers are mainly insectivorous birds widely distributed in America (Gorman 2014) that also feed on fruits (Hilty and Brown 1986, Stiles