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Diet composition of nestlings and adults of the threatened Bolivian Swallow-tailed Cotinga *Phibalura flavirostris boliviana* (Aves: Passeriformes: Cotingidae) in Bolivia

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Abstract: The qualitative and quantitative composition of the nestling and adult diet of the threatened Swallow-tailed Cotinga *Phibalura flavirostris boliviana* was studied through the analysis of fecal samples. Nestling diet consisted of 62% fruit and 38% insects but varied according to the nestling age. The diet of adults was made up of 89% fruit and 11% insects. The fruit eaten came primarily from the trees *Schefflera morototoni, Hyeronima moritziana* and *Ocotea cuprea.* Most insects in the fecal samples were winged-species of the orders Hymenoptera and Coleoptera. This species relied mostly on fruiting trees from semi-humid forest fragments and isolated trees on mountain savannas. Thus, management plans for this bird should consider the conservation of these habitats.

Keywords: Frugivorous bird, fecal samples, fruit, insects, nestling diet, Neotropical bird, *Schefflera morototoni.*

Frugivory in humid tropical zones is more common than in temperate zones because fruit is abundant, easy to obtain and often available all year round (Stutchbury & Morton 2001). Total frugivory, however, is rare in tropical birds (Morton 1973). Although Neotropical birds such as manakins (Pipridae) and cotingas (Cotingidae) are considered frugivorous, they supplement their diet with arthropods and small vertebrates, and feed their nestlings partially or wholly on arthropods (Morton 1973; Moermond & Denslow 1985; Stutchbury & Morton 2001). Most fruit contains few nutrients (Moermond & Denslow 1985; Herrera 2001) and a supplementary diet of arthropods containing higher amounts of proteins, permits more rapid growth and development of nestlings (Morton 1973). The advantage of consuming animal protein in this way, likely explains the reports of insects in the diet of nestlings for some frugivorous birds such as Cock-of-the-rock (Luy & Bigio 1994; Snow 2004), Long-wattled Umbrellabird (Karubian et al. 2003), Red-ruffed Fruitcrow (Muir et al. 2008), Cinnamon-vented

Phibalura flavirostris boliviana
Swallow-tailed Cotinga

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Piha (Willis & Oniki 1998), Blue-backed Manakin (Snow 2004), and other species like Resplendent Quetzal (Wheelwright 1983).

The plant families reported to be eaten by cotingas are: Cecropiaceae (*Cecropia* spp.), Araliaceae (*Schefflera morototoni*), Lauraceae, Burseraceae, Palmae, Myristicaceae and Loranthaceae (Snow 1981, 2004). These fruits are generally rich in lipids, proteins and carbohydrates (Snow 2004). The animal diet of cotingas include lizards, amphibians and an array of insect species (Snow 2004). Among these insect taxa are reports of Orthoptera, Mantodea, Coleoptera, Blattodea (Willis & Oniki 1998) and Hymenoptera (Snow 2004).

The Swallow-tailed Cotinga *Phibalura flavirostris* is a Neotropical species that consumes fruit and insects (Snow 2004). It is represented by a subspecies in the Atlantic forest of eastern Brazil (*Phibalura flavirostris flavirostris)* and another in the Andes of northwestern Bolivia (*Phibalura flavirostris boliviana*). Recent evidence support the *Phibalura* to be a member of the Cotingidae family within Phytotominae clade (Berv & Prum 2014). Both these subspecies are threatened by habitat loss and the Bolivian population *Phibalura f. boliviana* has been considered as a separate and Endangered species (IUCN 2012). Adults of the Bolivian population (Image 1), that inhabit semi-humid forest fragments in Apolo valley (1400–2000 m), were anecdotally observed feeding on fruits of *Schefflera morototoni* and catching insects in flight (Bromfield et al. 2004; Avalos 2009). However, quantitative details on the diet composition of adults and nestlings of this species are scarce. This information is important, given that the species deserves special conservation in Bolivia. Here, I quantify the nestling diet of the Bolivian Swallow-tailed Cotinga during its breeding months, as well as describing the adult diet during the breeding season.

Methods

I collected fecal samples near the village of Aten ($68^0$19’53”W & $14^0$55’56”S, elevation 1400–1690m) in the municipality of Apolo, Department of La Paz, Bolivia (Image 2). This site is situated in the western part of the Andes mountain chain. This fragmented landscape is comprised of semi-humid forest fragments, mountain savannas and grassland zones. The small forest fragments are situated between ridges, ravines and hillsides (Foster & Gentry 1991). Several plants species such as *Tapirira guianensis*, *Cecropia* spp., *Hyeronima alchornoides*, *Clusia* spp., *Nectandra cissiflora*, *Ficus* spp., *Pseudolmedia* spp., *Elaeagia microcarpa*, *Cyathea* spp., *Ormosia bopiensis* can be found in Aten (Verónica del Rosario Avalos pers. obs.). The mountain savanna of Aten consists of shrubs and small trees like *Alchornea triplinervia* and *Schefflera morototoni* scattered over the mountain savanna. The vegetation formation comes from the pluvial and humid forests of the subandean region (series *Eschweilera andina-Oenocarpus bataua*), which is actually substituted in part by anthropogenic savannas (Navarro & Maldonado 2002). The changes were induced by ancestral destruction and bad natural resource management. The climate is seasonal, characterized by a wet season from October to March, and a dry season from April to August.

I collected fecal masses of nestlings from under seven nests every 2–4 days from November 2005 to February 2006, following recommendations by Sutherland

Image 1. *Phibalura flavirostris boliviana* and fledglings in Aten, Apolo, Bolivia.

Image 2. The habitat of Phibalura flavirostris boliviana in Aten, Apolo, Bolivia.

(2004). The fecal masses, which consisted of fruit pulp, seeds and insects, were preserved in 70% ethanol. In the laboratory, I visually estimated proportions of fruit volumes (seeds and pulp remains), and insect using a 4x–stereoscope. Fruits were identified comparing seeds from plants collected in Aten and using botanic references from the National Herbarium of Bolivia (HNB). The number of fruits in each sample was estimated by counting the number of seeds that each fruit could contain. The arthropod remains were determined to the Order level using published identification keys (Ralph et al. 1985; Borror et al. 1989). Arthropod fragments sufficiently large to be identified, such as head capsule and thorax were quantified and mounted on glass slides for classification.

I determined the diet of adult birds by collecting fecal samples from under perches in trees (Sutherland 2004) or below nests that had been deserted during

Table 1. Relative frequency of fruit and insects (%) in fecal masses of nestlings (N = 51) and adults (N = 28) of Bolivian Swallow-tailed Cotinga collected from November 2005 to February 2006 at Aten, Bolivia. The number of specimens of insects per taxon is separated by a slash.

Fruit			Insects		
Plant species	**Nestlings %**	**Adults %**	**Taxon of insects**	**Nestlings %**	**Adults %**
Araliaceae	**40.9**	**52.5**	**Hymenoptera**	**58.5**	**54.3**
Schefflera morototoni	38.7	43.0	Apocrita	18.4/4	20.0/3
Schefflera patula	2.14	4.5	Formicidae		
Schefflera aff. tipuanica	0.03	5.0	Ponerinae	27.5/4	14.3/1
Dendropanax sp.	0.03	-	Myrmicinae/ Non-identified	5.8/3	17.2/1
Euphorbiaceae	**17.26**	**11.1**	Myrmicinae/ *Attini* sp.	5.3/1	-
Hyeronima moritziana	15.93	11.1	Myrmicinae/ *Atta* sp.	0.5/1	2.8/1
Hyeronima alchornoides	0.13	-	Pheidolini	1.0/1	-
Alchornea triplinervia	1.2	-	**Coleoptera**	**25.6**	**28.5/1**
Lauraceae	**16.11**	**14.7**	Carabidae	25.1/8	-
Ocotea cuprea	16.11	14.7	Scolytidae	0.5/1	-
Myrtaceae	**6.04**	**0.3**	**Homoptera**	**13.1**/7	**5.7**/1
Myrcia cf. *fallax*	4.2	0.3	**Lepidoptera** (larva)	**0.5/1**	-
Myrcia paivae	1.84	-	**Isoptera**	**0.5 /1**	-
Myrsinaceae	**4.86**	**15.7**	**Non-identified**	**0.5/2**	**11.4/1**
Myrsine coriacea	3.1	15.7			
Myrsine aff. pubipetala	1.76	-			
Melastomaaceae	**4.38**	**0.6**			
Miconia poeppigii	3.34	0.6			
Miconia sp. 1	0.69	-			
Miconia sp. 2	0.35	-			
Salicaceae	**3.85**	**1.5**			
Casearia arborea	3.85	1.5			
Annonaceae	**3.77**	**1.8**			
Guatteria cf. *tricloclonia*		1.8			
Solanaceae	**1.12**	**-**			
Lycianthes sp.	0.24	-			
Solanum sp.	0.88	-			
Burseraceae	**1.02**	**0.3**			
Protium sp.		0.3			
Erythroxylaceae	**0.4**	**1.8**			
Erythroxylum ulei		1.8			
Unidentified fruit (6 sp.)	**0.22**	**1.2**			

the incubation period. The composition of each fecal sample was expressed as relative frequencies of foods items, calculated by dividing the number of items in each taxonomic category by the total number of recorded items (expressed as percentages). The fecal masses of nestlings were grouped in five age classes (expressed in days): 1 = 6–9; 2 = 10–13; 3 = 14–17; 4 = 18–22; 5 = 23–27, according to the development of nestlings. Average proportions of items in each nestling age class were used to analyze the variation of fruit and insects. I used the G–test of independence to analyze the variation in fruit and insect proportion, and according to the different nestling age classes. To analyze the variation of diet during the breeding season studied, the fecal masses of seven nests were grouped into an early (November–December) and a late (January–February) periods. Variation in fruit and insect compositions of the two periods was analyzed using the G-test of independence. Significance of the test was checked at $\alpha = 0.05$. I used the R version 2.15.1 (R Development Core Team 2012) for this purpose.

Results

Nestling diet

Fecal masses of nestlings (n = 51) contained fruit (62%, range 10–100 %) and insects (38%, range 0–90 %). The nestling diet varied according to the five predefined nestling age classes (G–test of independence, G = 32.4, df = 4, P < 0.001). Insects comprised 57% and fruit 43% in nestlings aged 6 to 9 days and in nestlings beginning from 14 to 17 day of age, fruit increased to 70% (Fig. 1). Fruits identified belonged to 27 plant species of 11 families (Table 1) such as Araliaceae, mainly represented by *Schefflera morototoni* (39%), Euphorbiaceae, represented by *Hyeronima moritziana* (16%), and Lauraceae represented by *Ocotea cuprea* (16%).

Fruit composition of nestling fecal masses varied significantly between the breeding periods (G = 38.9, df = 5, *P* < 0.001). Araliaceae (*S. morototoni*) was most frequently represented in the diet during November and December followed by Myrsinaceae, Annonaceae and Melastomataceae, and fruit such as Lauraceae, Euphorbiaceae, Myrtaceae, Salicaceae and Araliaceae during January and February. The fruiting trees such as *Schefflera patula*, *Ocotea cuprea*, *Guatteria* cf. *tricloclonia* and *Protium* sp. were found in small forest fragments in the middle of ridges. *S. morototoni* was also found isolated in the mountain savanna (near the forest edge) and at the edge of the forest fragments.

The insect-part of the nestling diet comprised mostly of five orders (Table 1). Winged ants and wasps (Hymenoptera mainly represented by Ponerinae and Myrmicinae) were most frequent (58%), followed by Coleoptera (25%) and Homoptera (13%). The insect composition of the diet varied significantly between the periods (G = 51.5, df = 5, *P* < 0.01). Beetles, winged ants of the family Myrmicinae and other Hymenoptera were the main component of the nestling diet in the early breeding period, and winged ants of Ponerinae and other Hymenoptera predominated during the late breeding period.

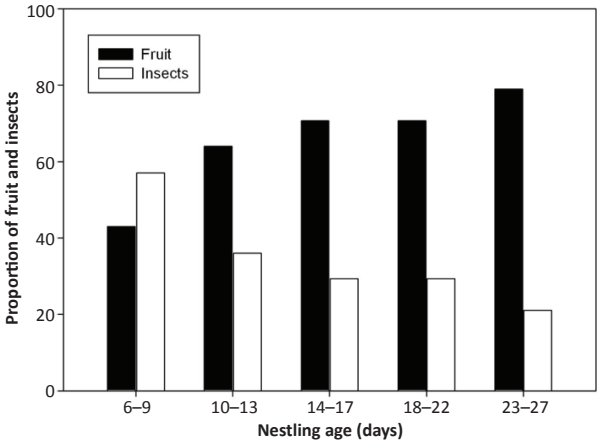

Figure 1. Percentage of fruit and insects in nestling diet of Bolivian Swallow-tailed Cotingas according to age classes.

Adult diet

The adult diet composition during the breeding months (from 20 fecal samples collected under perches of trees and eight samples collected in deserted nests) was comprised of 89% fruit (range 60–100 %) and 11% insects (range 0–40 %). All fecal samples of deserted nests contained a mixture of fruit and insects, whereas only 57% of fecal samples collected under perches contained fruit and insects. The fruit consumed by adults consisted mainly of *S. morototoni* (43%), followed by *O. cuprea* (15%) (Table 1). The insect-part of the diet was composed mainly of wasps and winged ants (54%), followed by Coleoptera (28%)(Table 1).

Discussion

The diet of fruit and insects

A substantial proportion of the nestling diet of the Bolivian Swallow-tailed Cotinga was comprised of insects, which is consistent with data from several other species of cotingas (Snow 2004; Muir et al. 2008) and other frugivorous birds (i.e., Wheelwright 1983). Adult birds complement the low-protein content of fruit with insects in order to improve the growth and development of nestlings (Morton 1973; Moermond & Denslow 1985; Stutchbury & Morton 2001). However, as nestlings were

14 days old, fruit increased throughout the nestling period up to 50%, which is similar with nestlings of frugivorous birds such as fruitcrows (Muir et al. 2008). An increase in fruit diet prolongs the length of the nestling period for frugivorous birds (Morton 1973; Stutchbury & Morton 2001), and most cotingas are reported to have long nestling periods (Snow 2004). The nestling-period length for Swallow-tailed Cotinga was 27 days (Avalos 2011), probably a long period that might indicate the influence of fruits for this small to medium-size cotinga.

On the other hand, it is yet unsure if insects are eaten by adults year around. Even if the adults were seen foraging intensely on insects (Avalos 2009), that does not imply they are more insectivorous than nestlings. In fact, 57% of the fecal samples of adults analyzed, and the stomach content of one adult collected in September 2009 (sample # 4700 of Colección Boliviana de Fauna) contained only fruits. This pattern could be explained as a strategy in which adults eat mainly fruits and most insects caught are feed to nestlings (Morton 1973; Moermond & Denslow 1985; Stutchbury & Morton 2001). However, the insectivory could be seasonal or less frequent during some seasons. More information on the availability of food resources and diet in the habitat all year round is needed for better comprehension of resource exploitation.

The fruit composition of nestlings varied according to breeding months studied, suggesting that it could be related to the availability and energy content of ripe fruits. Indeed, at the end of the year the *S. morototoni* fruit were ripe, and when the fruiting stage ended, nestlings were predominantly fed with *Ocotea* spp., *Hyeronima* spp. and other fruiting plants that are found in semi-humid forest fragments. Although data on nutritional content of each fruiting plant is scarce, nutritional data of fruiting families indicate that fruits of Euphorbiaceae, Myrsinaceae, Melastomataceae, Annonaceae, and Salicaceae have a high content in carbohydrates (see Snow 1981; Moermond & Denslow 1985), that could supplement the nestlings diet. *S. morototoni* and *Ocotea* spp. have a high content of proteins and lipids in their fruits (Snow 1981, 2004) that could be important to enhance the growth and development of nestlings.

Overall, three or four plant species are suggested to be important for many frugivorous birds, such as cotingas (Moermond & Denslow 1985; Snow 2004). *Schefflera morototoni* was very important during the breeding periods for adults and nestlings of Bolivian Swallow-tailed Cotinga, similarly to the Cock-of-the-rocks (Snow 1971; Schuchmann 1984; Luy & Bigio 1994). In contrast, the Brazilian Swallow-tailed Cotingas eat the mistletoe fruit of Loranthaceae, Myrsinaceae and Rubiaceae (Snow 1982; Pizo et al. 2002; Snow 2004). The high proportion of *S. morototoni* in the diet of the Bolivian Swallow-tailed Cotinga could be influenced by the availability of the fruiting trees. This plant species in different places of Bolivia have flowers and immature fruits throughout majority of the year, except May and January (pers. revision in HNB). The knowledge of fruiting phenology, abundance and tolerance to fires of this plant species, could be useful for a greater understanding of the feeding habits of the Bolivian Swallow-tailed Cotinga.

Conservation implications

Adults and nestlings of Bolivian Swallow-tailed Cotinga consumed fruits from fruiting trees that are found in forest fragments. The birds foraged at isolated trees of *S. morototoni* which grew near forest fragments (Avalos 2009), similar to some cotingas that forage for fruits in open areas near the forests (Pizo et al. 2002; Silva et al. 2002) or toucans that forage at *Ficus* trees in grasslands (Graham 2001). However, even though this species uses modified human impacted landscape, it does not indicate that a viable population could be sustained in an extensively modified habitat. A continuation of habitat modification caused by fires and cattle on the mountain savanna and in the semi-humid forest fragments of the Apolo valley could diminish the availability of many fruiting trees that may compromise the bird feeding. My data suggests that any management plan must include contingencies for the conservation of forest fragments, including the small patches of trees and shrubs in mountain savannas, to sustain the food resources needed for Bolivian Swallow-tailed Cotinga.

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