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GIZZARD CONTENTS OF THE SMOOTH-BILLED ANI *CROTOPHAGA ANI* IN SANTA CRUZ, GALAPAGOS ISLANDS, ECUADOR

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SUMMARY

The Smooth-billed Ani *Crotophaga ani* was introduced to the Galapagos archipelago in the 1960s, since when its population has grown significantly. We studied the dietary items in the gizzards of 56 anis sampled on the island of Santa Cruz. We confirmed that the diet of *C. ani* consists primarily of invertebrates and plant material, including native species and non-native invasives. The second most abundant seed in the anis' diet was that of the highly invasive plant, *Rubus niveus*. Our findings suggest that *C. ani* poses a threat to the Galapagos ecosystem by dispersing seeds of non-native plants and by competing with other insectivorous species on the islands. Furthermore, the discovery of a Darwin's Finch nestling in the gizzard of one *C. ani* establishes direct predation by this species on native birds.

RESUMEN

Contenido de la molleja del Garrapatero aní *Crotophaga ani* en Santa Cruz, Galápagos, Ecuador. El Garrapatero aní *Crotophaga ani* fue introducido en el archipiélago de Galápagos en los años 60 y desde entonces su población ha crecido significativamente. Estudiamos los elementos dietarios en las mollejas de 56 garrapateros colectados en la isla de Santa Cruz. Confirmamos que la dieta de *C. ani* consiste principalmente de invertebrados y materia vegetal, incluyendo especies nativas e invasoras no-nativas. La segunda semilla más abundante en la dieta de los garrapateros fue la de la planta altamente invasora, *Rubus niveus*. Nuestras observaciones sugieren que *C. ani* representa una amenaza al ecosistema de Galápagos ya que dispersa semillas de plantas no-nativas y compete con otras especies insectívoras en las islas. Además, el hallazgo de un pichón de pinzón de Darwin en el gizzard de un *C. ani* establece la directa predación de esta especie sobre aves nativas.

INTRODUCTION

Many Galapagos endemic birds are threatened by loss of habitat, introduced diseases, and competition and predation from introduced species (Grant 1999, Fessl & Tebbich 2002, Deem *et al.* 2008, Wiedenfeld & Jiménez-Uzcátegui 2008, Parker 2009). Ten bird species, including Cattle Egret *Bubulcus ibis* and Smooth-billed Ani *Crotophaga ani*, have been introduced to the Galapagos (Jiménez-Uzcátegui *et al.* 2007). The Smooth-billed Ani (from here on called ani) is considered one of the most detrimental to native birds and other wildlife in the Galapagos (Rosenberg *et al.* 1990).

The ani is native to the southern regions of North America and throughout Central and South America. It frequently feeds in groups, and prefers open habitat to dense forests (Ridgely & Greenfield 2001). On the South American mainland, anis are omnivores with a diet consisting mainly of insects (*e.g.* grasshoppers, caterpillars

and moths), and occasionally small vertebrates such as baby birds, frogs and lizards; additionally plants make up an important part of their diet, especially during the dry season (<http://bna.birds.cornell.edu/bna/species/539> consulted 2 Dec 2010). On the mainland, anis are commonly attracted by the insects that live on and around livestock (Ridgely & Greenfield 2001).

Anis were first recorded in the Galapagos in the 1960s, and there were an estimated 800 birds on the island of Santa Cruz in 1984 (Ballesteros 1984, Rosenberg *et al.* 1990). The last survey of ani populations, conducted between 1986 and 1987, provided an estimate of 4800 anis on Santa Cruz and 100 on Isabela Island (Rosenberg *et al.* 1990). Anis may have been initially introduced to the archipelago to control ticks on cattle (Rosenberg *et al.* 1990). However, anis have not been observed in strong association with cattle and appear to be dispersed throughout all vegetation zones. During the 1980s, anis were recorded on nine Galapagos islands: Santa Cruz, Isabela, Daphne, Genovesa, Santiago,

Floreana, Pinzon, Santa Fe and San Cristóbal (Rosenberg *et al.* 1990). Because of perceived threats associated with anis, including competition with endemic bird species, dispersal of introduced plants and spread of avian diseases, Rosenberg *et al.* (1990) recommended that anis be eradicated from the Galapagos.

Anis have increased since the surveys of the 1980s. In 2010, 80,000 anis were estimated on Santa Cruz, with a total of 250,000 across the archipelago (VC unpubl. data). Anis apparently lack competitors and have few predators in the Galapagos, which likely contributes to their success and continued spread. The growth of the ani population and presumed threat to native biota indicate the importance of understanding the ecology and impacts of this species. As a step towards this, the objective of this study was to examine the diet of anis on Santa Cruz by analyzing the contents of their gizzards.

MATERIALS AND METHODS

Ani gizzards were gathered between 5 Nov and 8 Dec 2009. Anis were collected at six locations in the Dry, Transition and Humid vegetation zones of Santa Cruz (Table 1). The Dry Zone, characterized by low rainfall and dry woodland and scrub, extends from sea level to c. 150 m above sea level, succeeded by the denser forests of the Transition Zone, up to c. 400 m. Above the Transition Zone is the Humid Zone. Santa Cruz also has an Agricultural Zone, which is located primarily within the Transition and Humid Zones, where it has displaced much of the native vegetation (Guerrero & Tye 2009). The gizzards were collected from birds hunted by Galapagos National Park (GNP) rangers as part of a pilot study for an attempt to eradicate anis from the archipelago, and in order to determine whether the anis harbour a recently discovered *Plasmodium* sp. which affects the Galapagos Penguin *Spheniscus mendiculus* (Levin *et al.* 2009). GNP rangers, using Ruger 22 Charger Rimfire Pistols and Ruger Mini-14 Ranch Rifles (Sturm, Ruger & Co., Inc., Newport, NH), opportunistically shot anis they located in the field.

The organs, including the gizzard, of each bird retrieved were collected for necropsy by SLD. For the first 27 samples, the intact gizzards were excised from the birds and placed in small plastic Nalgene bottles in the field. For the remaining 28 samples the contents of each gizzard were extracted in the field by opening the gizzard and

placing all contents into a cryotube. Samples were kept in a cooler in the field and placed in a -20°C freezer upon returning to the lab. In cases in which the gizzard was too damaged to analyze its contents completely, significant features were recorded (*e.g.* types and numbers of seeds).

Contents were analyzed within two months of collection. Samples were thawed for at least 15 min. prior to examination. The intact gizzards were cut open and the contents extracted. LC separated the contents of each sample, in a Petri dish, into three categories: insect, plant and seed, and indistinguishable (Fig. 1), using a Nikon Field microscope Mini. Each category was then further subdivided. Seeds were separated by their appearance, given descriptive names and counted. When possible, insects were separated by their appearance, given descriptive names (*e.g.* moth, beetle, caterpillar) and counted. There were many unidentifiable insect parts. The insects were further analyzed by HWH and the seeds by AG. Insects that could be identified were classified as endemic, non-endemic native, or introduced. Seeds that were identified were classified as native (none was endemic) or introduced.

RESULTS

Gizzards from four of the anis were destroyed by the gunshot wound and thus only a brief observation was made in the field. The contents of the other 52 gizzards were fully analyzed. The majority of the contents were categorized as either invertebrates or plant material. Most of the identifiable plant material was in the form of



Figure 1. Petri dish with the separated gizzard contents of one Smooth-billed Ani. Unidentifiable matter has been removed, seeds are in the upper right and insect parts fill the majority of the lower and left of the Petri dish. (Photo: Lillian Connett.)

Table 1. Sites of Smooth-billed Ani collection on Santa Cruz Island, Galapagos.

Site Name	Coordinates (S, W)	Zone	n gizzards
Road to Garrapatero	0°40'7", 90°15'41"	Dry	13
El Mirador	0°43'57", 90°19'14"	Transition	8
Parque Artesanal	0°43'4", 90°19'49"	Transition	5
Finca de Carrión	0°41'17", 90°21'41"	Humid	17
Finca de Kastdalen	0°41'8", 90°18'53"	Humid	4
Reserva Pájaro Brujo	0°39'14", 90°24'32"	Humid	9

seeds. A few leaf and other plant pieces were detected, but they were unidentifiable. Seeds were identified in 37 birds (71 %), with a total of 5826 seeds classified. Twelve out of 13 birds (92 %) from the Dry Zone had consumed seeds, which accounted for 62 % (by number) of the total seeds found. Twelve out of 13 specimens (92 %) from the Transition Zone had consumed seeds, accounting for 19% of all seeds found. Eleven out of 30 specimens (37 %) from the Humid Zone had consumed seeds, which accounted for 19 % of all seeds found.

Seeds from 11 plant species were recorded (Table 2), of which three were introduced species. Six species were native (Table 2). Among the introduced species, only 30 seeds from *Lantana camara* were found (from five gizzards), all in the Transition Zone. In contrast, seeds from *Rubus niveus* were numerous (1064 seeds from 11 gizzards) and primarily found in the Humid Zone, with the exception of eight seeds in one gizzard from the Transition Zone. The seeds of *Solanum pimpinellifolium* (405 seeds from eight gizzards) were all found in the Transition Zone.

Of the 3622 seeds found in the Dry Zone, 3507 were from four native species and 115 from two unidentified species. Of the 1083 seeds collected in the Transition Zone, 640 were from five native species and 443 from three introduced species. Of the 1121 seeds found in the Humid Zone, 63 were from two native species, 1056 from one introduced species and two from an unidentified *Desmodium* species. The average number of seeds per bird (of birds that had consumed seeds) was 301 in the Dry Zone, 90 in the Transition Zone and 101 in the Humid Zone.

Invertebrates were found in 51 of the 52 gizzards (98 %) (Table 3). Most fragments could not be identified, so the data in Table 3 are not representative of the scope of the

ani diet. However, 153 specimens were classified to order, including 19 specimens classified to genus level only and an additional 34 classified to species. Of the 53 specimens identified at least to genus level, 25 were classifiable as native, 17 endemic and 11 introduced. In addition to the species identified in the gizzards, HWH has seen anis eating the endemic grasshopper, *Schistocerca melanocera*.

One Darwin's finch nestling (species undetermined) was recovered from the gizzard of an ani in the Dry Zone, on 5 Nov 2009. An ani was also recently photographed eating an introduced mouse, *Mus musculus* (Fig. 2), and B. Fessl (pers. comm.) has recorded anis eating lizards on Santa Cruz.

DISCUSSION

This study documents some effects of anis on the Galapagos flora and fauna, and confirms several earlier predictions (Rosenberg *et al.* 1990). While Rosenberg *et al.* (1990) conducted their study of gizzard contents at a similar time of year (Nov–Dec 1986), they did not find many seeds. They ranked items by weight and frequency, and seeds ranked eighth out of nine by weight and 5.5 out of nine for frequency (nine being the lowest rank for both weight and frequency). However, subsequent studies documented substantial seed consumption by anis and suggest that anis could be contributing to major ecosystem changes in the Galapagos. Guerrero & Tye (2011) found six species of seeds in the gizzards of anis, including four species found in our study (*Solanum americanum*, *Tournefortia psilotachya*, *L. camara*, and *R. niveus*). Soria Carvajal (2006), looking specifically at the dispersal of *R. niveus*, found anis to be the largest avian consumers

Table 2. Seeds identified from the gizzards of anis on Santa Cruz Island, Galapagos. Data are presented as: n seeds (n gizzards).

Seed species	Totals	Transition		Humid		
		Dry Road to Garrapatero	Parque Artesanal	El Mirador	Finca de Carrión	Finca de Kastdalen
Native species						
<i>Cordia lutea</i> Lam.	4 (2)			4 (2)		
<i>Chiococca alba</i> (L.) Hitchc.	17(2)		17 (2)			
<i>Solanum americanum</i> Mill.*	3173 (14)	2799 (7)	298 (4)	17 (1)	59 (2)	
<i>Tournefortia psilotachya</i> Kunth	992 (14)	703 (9)		289 (5)		
<i>Vallesia glabra</i> (Cav.) Link	4 (1)	4 (1)				
<i>Zanthoxylum fagara</i> (L.) Sarg.	20 (5)	1 (1)	15 (1)		4 (3)	
Total Natives	4210 (27)	3507 (12)	640 (11)	63 (4)		
Introduced species						
<i>Lantana camara</i> L.	30 (5)		12 (1)	18 (4)		
<i>Rubus niveus</i> Thunb.	1064 (11)		8 (1)		360 (4)	696 (6)
<i>Solanum pimpinellifolium</i> L.	405 (8)		260 (4)	145 (4)		
Total Introduced	1499 (19)	0	443 (9)	1056 (10)		
<i>Desmodium</i> sp.	100 (2)	98 (1)				2 (1)
Unknown species	17 (3)	17 (3)				
Total Unidentified	117 (4)	115 (3)	0	2 (1)		
Totals	5826 (35)	3622 (12)	610 (5)	473 (7)	423 (5)	698 (6)
		3622 (12)		1083 (12)		1121 (11)

*Until recently, often regarded as introduced to Galapagos, but shown to be native by Coffey *et al.* (2011).

Table 3. Invertebrates identified from the gizzards of anis on Santa Cruz Island, Galapagos. Data are n invertebrates identified (n gizzards containing given invertebrate species).

	Totals	Dry	Transition		Humid		
		Road to Garrapatero	El Mirador	Parque Artesanal	Finca de Carrión	Finca de Kastdalen	Reserva Pájaro Brujo
Native species							
<i>Xylocopa darwini</i> ¹	12 (12)	5 (5)	3 (3)	1	2 (2)		1
<i>Perepitragus fuscipes</i> ²	2 (2)		2 (2)				
<i>Neoconocephalus triops</i> ³	5 (5)	1			3 (2)		1
<i>Anaulocamera darwini</i> ³	1				1		
<i>Podisus sp.</i> ⁴	1				1		
<i>Podisus sordidus</i> ⁴	1	1					
<i>Acrosternum sp.</i> ⁴	1	1					
<i>Acrosternum viridans</i> ⁴	2 (2)	2 (2)					
Total natives	25 (19)	10 (8)	6 (5)	9 (6)			
Endemic species							
<i>Galapaganus spp.</i> ²	14 (13)	3 (3)			8 (7)		3 (3)
<i>Gryllus abditus</i> ³	1			1			
<i>Halmerus robustus</i> ³	1		1				
<i>Nesoecia cooksoni</i> ³	1	1					
Total endemics	17 (16)	4 (4)	2 (2)	11 (10)			
Introduced species							
<i>Copiphora brevicauda</i> ³	3 (3)				1		2 (2)
<i>Anasa spp.</i> ⁴	2 (2)	2 (2)					
<i>Anasa scorbutica</i> ⁴	3 (3)	3 (3)					
<i>Nezara sp.</i> ⁴	1			1			
<i>Nezara viridula</i> ⁴	2 (2)	1	1				
Total introduced	11 (10)	6 (5)	2 (2)	3 (3)			
Totals	53 (32)	20 (11)	7 (4)	3 (2)	16 (9)	0	7 (6)
		20 (11)		10 (6)		23 (15)	

Order: ¹Hymenoptera; ²Coleoptera; ³Orthoptera; ⁴Hemiptera.



Figure 2. An adult Smooth-Billed Ani with a mouse, *Mus musculus*, in its beak, on Santa Cruz Island. (Photo: Luis Die.).

of its fruit in the Galapagos, and that ani consumption of *R. niveus* remained fairly consistent in wet and dry seasons. Seeds were clearly a large part of the diet for anis in our study, with 71 % of ani gizzards having seeds, and seeds frequently making up the majority of the gizzard contents.

All three introduced plant species whose seeds we found in ani gizzards are invasive in Galapagos (Tye 2001). Most worrisome is the high number of *R. niveus* seeds identified, in three separate studies. This was the second most abundant seed found by us (> 1000 seeds), and we conclude that anis may contribute importantly to the dispersal of *R. niveus*. The plant species for which the most seeds were found (*R. niveus* and *S. americanum*) both have fruits that contain many seeds, whereas fruits of the five native species found typically have fewer seeds per fruit.

Birds contribute to the establishment of plants in new areas (Garcia *et al.* 2010, Herrera *et al.* 2010). *R. niveus* seeds collected from ani feces were viable (Soria Carvajal 2006). In contrast, very few of the *R. niveus* seeds gathered from the feces of native Galapagos birds were viable, suggesting that anis are superior dispersers of *R. niveus* (Soria Carvajal 2006). Guerrero & Tye (2011) found that most seeds recovered from the gizzards of anis were viable. These two studies also suggest that anis serve

as effective dispersers, but further data on viability of a range of seeds from ani feces would be useful.

Much of the ani's diet is composed of invertebrates, including many native and endemic species. As native and endemic invertebrate populations are stressed by competition (Causton *et al.* 2006), loss of habitat and the use of pesticides, these populations could suffer from additional pressure from an ever-growing population of anis. Furthermore, the ani's appetite for invertebrates puts it in direct competition with other birds that rely on these same invertebrates, especially during dry periods when food is short (Rosenberg *et al.* 1990).

While occasional ani predation on baby birds has been recorded before in locations in mainland South America and suspected to occur on the Galapagos Islands (Rosenberg *et al.* 1990), the Darwin's finch (Geospizinae) nestling found in this study is the first confirmation of ani predation on nestlings in the Galapagos Islands. The specimen is frozen and available for future genetic testing to determine the species, although it is probable that all Geospizinae species are predated. Our study was conducted during a dry period at the start of the nesting season for terrestrial Galapagos birds and thus few nestlings would have been available at the time. Further study of the ani's eating habits during the wet season (which is peak finch nesting season, but also the time of highest fruit and insect availability) is needed to determine if anis prefer nestlings or if they prey on them only when other food sources are limited. Either way, such predation by anis is troublesome at a time when nesting success of several native bird species is already low due largely to the introduced fly *Philornis downsi* (Fessl & Tebbich 2002, Dudaniec *et al.* 2006).

Ani predation on introduced rodents (Fig. 2) complicates the matter of eradicating the ani, as this might lead to rodent increase. Introduced rodents, such as *M. musculus*, adversely affect native Galapagos species and ecosystem functioning (Harper & Cabrera 2009). Thus, if anis are a significant predator of *M. musculus*, it may be necessary to pair efforts to eradicate the ani with similar efforts to eradicate invasive rodents.

Further information on the ani's eating habits may exist in Jara (1995) but we were unable to obtain this document.

Given the diet of the ani, their presence throughout the islands is most likely causing an impact on the Galapagos ecosystem. The spread of the seeds of invasive plants by anis may contribute to changing the landscape of the islands. Their high dietary preference for invertebrates adds stress on native birds and invertebrates in the form of competition and predation, respectively. And at a time when terrestrial bird populations are experiencing a number of threats in the Galapagos, predation by anis may be an added pressure (Fessl & Tebbich 2002, Deem *et al.* 2008, Wiedenfeld & Jiménez-Uzcátegui 2008, Parker 2009).

Although eradication of the ani will be difficult, given their numbers and wide distribution, our studies suggest it should be a priority, to ensure ecosystem health.

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