ACTA BIOLÓGICA COLOMBIANA
http://www.revistas.unal.edu.co/index.php/actabiol

Facultad de Ciencias
Departamento de Biología
Sede Bogotá

UNIVERSIDAD NACIONAL DE COLOMBIA

ARTÍCULO DE INVESTIGACIÓN / RESEARCH ARTICLE

ZOOLOGÍA

ON BIRDS OF SANTANDER-BIO EXPEDITIONS, QUANTIFYING THE COST OF COLLECTING VOUCHER SPECIMENS IN COLOMBIA

Sobre las aves de las expediciones Santander-Bio, cuantificando el costo de colectar especímenes en Colombia

Enrique ARBELÁEZ-CORTÉS[1]*, Daniela VILLAMIZAR-ESCALANTE[1], Fernando RONDÓN-GONZÁLEZ[2]

[1]Grupo de Estudios en Biodiversidad, Escuela de Biología, Universidad Industrial de Santander, Carrera 27 Calle 9, Bucaramanga, Santander, Colombia.

[2]Grupo de Investigación en Microbiología y Genética, Escuela de Biología, Universidad Industrial de Santander, Carrera 27 Calle 9, Bucaramanga, Santander, Colombia.

For correspondence: enriquearbelaez@gmail.com

Received: 23th January 2019, **Returned for revision**: 26th March 2019, **Accepted**: 06th May 2019.
Associate Editor: Diego Santiago-Alarcón.

Citation/Citar este artículo como: Arbeláez-Cortés E, Villamizar-Escalante D, and Rondón-González F. On birds of Santander-Bio Expeditions, quantifying the cost of collecting voucher specimens in Colombia. Acta biol. Colomb. 2020;25(1):37-60. DOI: http://dx.doi.org/10.15446/abc.v25n1.77442

ABSTRACT

Several scientific reasons support continuing bird collection in Colombia, a megadiverse country with modest science financing. Despite the recognized value of biological collections for the rigorous study of biodiversity, there is scarce information on the monetary costs of specimens. We present results for three expeditions conducted in Santander (municipalities of Cimitarra, El Carmen de Chucurí, and Santa Barbara), Colombia, during 2018 to collect bird voucher specimens, quantifying the costs of obtaining such material. After a sampling effort of 1290 mist net hours and occasional collection using an airgun, we collected 300 bird voucher specimens, representing 117 species from 30 families. Such collection represents one of the largest series obtained during the historical ornithological exploration of Santander. We report differences among expeditions regarding the capture rate in mist nets, as well as differences in the sizes of taxa collected by mist nets and airgun. We discuss results in the context of previous ornithological expeditions in Colombia, commenting issues on the biology of some species, particularly those considered as noteworthy records (*e.g.*, Red-legged Tinamou [*Crypturellus erythropus*], Cinnamon Screech Owl [*Megascops petersoni*], Saffron-headed Parrot [*Pyrilia pyrilia*], Black Inca [*Coeligena prunellei*], and Chestnut-crowned Gnateater [*Conopophaga castaneiceps*]). We calculated that the costs of obtaining and curating a specimen in Colombia, including tissues for molecular analysis, was ~US$60.4 (~$196 176 COP), which is among published costs of obtaining voucher specimens in other taxa and countries. These costs must be considered an investment in scientific capital because voucher specimens will provide biological information for hundreds of years.

Keywords: Biodiversity, biological collections, eastern Andes, middle Magdalena valley, ornithology.

RESUMEN

Hay distintas razones científicas que apoyan la recolección de aves en Colombia, un país megadiverso pero con una modesta inversión en ciencia. Pese al valor de las colecciones biológicas para el estudio riguroso de la biodiversidad, la información sobre costos monetarios de recolectar especímenes es escasa. Presentamos resultados de la cuantificación del costo de obtener especímenes de aves durante tres expediciones en Santander (municipios de Cimitarra, El Carmen de Chucurí y Santa Bárbara), Colombia, en 2018. Tras un esfuerzo de muestreo de 1290 horas/red y recolecta ocasional con una pistola de aire, obtuvimos 300 especímenes pertenecientes a 117 especies de 30 familias, una de las series más grandes de la historia de la exploración ornitológica del departamento de Santander. Reportamos diferencias entre expediciones en cuanto a la tasa de captura con redes de niebla, así como diferencias en los tamaños de los taxones recolectados mediante redes de niebla y pistola de aire. Discutimos los resultados en el contexto de otras expediciones ornitológicas en Colombia, comentando algunos aspectos de la biología de especies relevantes

(*e.g.*, *Crypturellus erythropus*, *Megascops petersoni*, *Pyrilia pyrilia*, *Coeligena prunellei* y *Conopophaga castaneiceps*). El costo que calculamos para obtener y curar un espécimen, incluyendo tejidos para análisis moleculares futuros, es de ~$60,4 dólares estadounidenses (~$196 176 pesos colombianos), costo que se encuentra dentro del rango para obtener especímenes de otros taxones en otros países. Estos costos deben considerarse como una inversión al capital científico, debido a que los especímenes brindarán información biológica por cientos de años.

Palabras clave: Biodiversidad, colecciones biológicas, cordillera Oriental, ornitología, valle del Magdalena medio.

INTRODUCTION

Voucher specimens housed at biological collections and natural history museums are fundamental for the rigorous scientific study of biodiversity (Yates, 1985; Nudds and Pettitt, 1997; Suarez and Tsutsui, 2004; Winston, 2007; Lavoie, 2013; Clemann *et al.*, 2014; Holmes *et al.*, 2016). Biological collections of megadiverse developing countries have immensely contributed to the knowledge of life (Paknia *et al.*, 2015). For instance, the rate of species description (the *sinequanum* taxonomic practice that uses voucher specimens) in Colombia represents between 2.5 and 10 % of all the new species of terrestrial vertebrates described around the World (Arbeláez-Cortés, 2013a). This result is particularly relevant for birds given that Colombia is the country with the largest number of bird species (Donegan *et al.*, 2016; Avendaño *et al.*, 2017b), and there is an average of one new species described per year (Arbeláez-Cortés, 2013a; Caycedo-Rosales *et al.*, 2014). The Colombian biological collections have a major role in the scientific study of the country's biodiversity (Arbeláez-Cortés *et al.*, 2017), and several gaps in current knowledge (*e.g.*, genetic diversity) can be filled up through collection of new specimens and by analyzing voucher material already catalogued in available collections (Arbeláez-Cortés, 2013b; Avendaño *et al.*, 2017a).

The recognized value of biological collections for scientific knowledge of biodiversity contrasts with the scarce information published on the monetary costs involved in obtaining voucher specimens (Yates, 1985; Blackmore *et al.*, 1997; Mann, 1997; Bradley *et al.*, 2012; Baker *et al.*, 2014; Bradley *et al.*, 2014). Such costs can be easily quantified for field expeditions of funded projects. Knowing the monetary costs of collecting and curating voucher specimens can be instrumental for institutions and government to evaluate the effective use of the allocated budget to activities related to biodiversity documentation. It is particularly crucial for Colombia, a country that only invests between 0.24 and 0.3 % of its GDP in research and development (The World Bank, 2018; UNESCO, 2018), but which houses large biodiversity (Sistema de Información sobre Biodiversidad de Colombia [SiB-Colombia], 2018).

In 2016, the Colombian government began a national initiative known as Colombia BIO that included projects to conduct 20 expeditions to inventory biodiversity in unexplored localities. The program helped to articulate academic and scientific institutions, consolidating biological collections of specimens and tissues for molecular analyses, and making publicly available the data through online databases (Ayala *et al.*, 2018). The model set by Colombia Bio expeditions was followed at a department level (*i.e.*, first administrative division of Colombia) in Santander (in northeastern Colombia) financed by funds from *Sistema Nacional de Regalia*s with the management of *Gobernación de Santander*, and was conducted linking the scientific capacities from *Universidad Industrial de Santander* (hereafter UIS) and *Instituto de investigación de recursos biológicos Alexander von Humboldt* (hereafter IAvH). The project had the name "*Investigación de la biodiversidad y los servicios ecosistémicos para la gestión integral del territorio – descubriendo los ecosistemas estratégicos para el fortalecimiento de la gobernanza en el departamento de Santander*" (hereafter Santander-BIO). UIS aimed to obtain new biological material to consolidate its collections of vertebrates, entomology, herbarium, hydrobiology, microbiology, and tissue samples for molecular analyses of some taxa. We developed the collection of bird voucher specimens and their tissues, along with occasional observational records of some species.

Different scientific reasons support the necessity of continuing collection of birds in Colombia (Cuervo *et al.*, 2006). During the last decades several ornithological expeditions contributing with voucher specimens to biological collections have been conducted in the country (Stiles and Bohórquez, 2000; Bohórquez, 2002; Alvarez *et al.*, 2003; Donegan *et al.*, 2007; Cuervo *et al.*, 2008a; Cuervo *et al.*, 2008b; Donegan *et al.*, 2010; López-Ordóñez *et al.*, 2013; Stiles and Beckers, 2016; Izquierdo *et al.*, 2017; Renjifo *et al.*, 2017; Stiles and Naranjo, 2017; Avendaño *et al.*, 2018b; Avendaño *et al.*, 2018a; Córdoba-Córdoba and Sierra, 2018), with some of them at Santander. The scientific documentation of Santander bird fauna encompasses more than 200 years (Avendaño, 2017), and at least 840 species have been recorded in this department according to eBird records (Rondón, 2017). Public information indicates that there are at least 5299 voucher specimens, and around 100 tissue samples, representing 648 species for Santander (Arbeláez-Cortés *et al.*, 2015; GBIF.org, 2018), but these are not yet representative of the bird biodiversity of this Colombian region.

The aims of our study were: 1) to present results of three ornithological expeditions conducted in Santander, Colombia, during 2018 to collect and preserve bird voucher specimens by the UIS in the framework of Santander-BIO project, commenting topics of the biology of some taxa and discussing results in the historical context of bird collection in Colombia in general and of Santander in particular; and 2) to quantify the monetary costs related to the bird specimens obtained, as an example of the costs during regional expeditions in Colombia, depicting some features related to collecting methods.

MATERIALS AND METHODS

Study area and field work

Santander is located on the western slope of the Colombian Eastern Andes (between 72.28° W and 74.31° W, and between 5.42° N and 8.08° N), occupying 2.7 % of the national territory (30 537 Km^2), and being the fourth department regarding population and economy in the country (Gobernación de Santander, 2016). There are two major physiographic units in Santander: 1) the Middle Magdalena valley (40 to 200 m.a.s.l) to the West that is characterized by a flat and undulated topography, and 2) the Colombian Eastern Andes (*i.e.*, *Cordillera Oriental*) which occupies most of the department, and is characterized by a steep topography that reach up to 4345 m.a.s.l. This heterogeneous region includes orographic accidents like the Serranía de los Yariguíes, river canyons such as Chicamocha canyon, and plateaus like the Mesa de Los Santos or Jéridas (Fig. 1). The annual median temperature and precipitation vary locally from less than 8 °C to more than 28 °C and from 500 to 3000 mm/year (IDEAM, 2015). According to Holdridge classification, there are 15 life zones in Santander, including tropical humid, very humid forest, dry forest, pre-montane dry forest, very humid montane forest, and pluvial montane forest (Instituto Geográfico Agustín Codazzi, 1976). The forests of Santander are highly fragmented, where only 16.3 % of its area remains covered by natural forests (mainly secondary forests). Agricultural plantations of palm, coffee, and cacao crops are in the rural areas, as well as extensive cattle ranches, which cover approximately 60.2 % of Santander's area (Secretaría de planeación de Santander, 2014). Areas that are still ecologically conserved are mainly located within natural reserves, including a national natural park (*Parque Nacional Natural Serranía de Los Yariguíes*) encompassing around 59 000 ha (Secretaría de Planeación de Santander and Universidad Industrial de Santander, 2011).

In the framework of Santander-Bio project, we conducted three expeditions during February-March, July, and August of 2018, developing fieldwork focused on collecting birds. Each expedition aimed to represent a different ecosystem of Santander. We named each expedition according to the name of the municipality (*i.e.*, second-order politic and administrative division of Colombia) where the fieldwork was conducted and avoid referring to them as localities because in two expeditions, we performed collection of birds in more than one locality within the zone (Table 1). The expeditions were conducted at the municipalities of Cimitarra (humid tropical forest), El Carmen de Chucurí (very humid pre-montane forest), and Santa Barbara (pluvial montane forest), which had scarce biological records according to biodiversity databases.

Each expedition was two weeks long, with effective fieldwork of 12 to 13 days. We focused our efforts on collecting mainly resident bird species inhabiting the interior of forests. Therefore, for each expedition, we placed ten to 13 mist nets (12 x 2.5 m) in the interior of the forests located around each campsite. Mist nets were mainly open at dawn (5:30 – 6:30 am) and closed before noon (10:00 -11:00 am), but some days mist nets were also opened at noon and during the afternoon (2:00 - 5:00 pm). The collection effort was calculated considering one mist net hour as a mist net of 12 m open for one hour (Table 1). In parallel, a fieldwork assistant with military training helped us conducting an occasional and opportunistic collection of birds around campsites during two expeditions by using an airgun pistol Crossman 5.5. Finally, on two opportunities, we recovered salvaged specimens (*i.e.*, individuals dead by collision with human structures that were preserved as specimens). Details about the expeditions, the localities we worked, and the sampling effort are depicted in Table 1. We collected at least one specimen for each species captured except for the migrant Swainson's Thrush (*Catharus ustulatus*) of which we captured and released one individual at El Carmen de Chucurí. This project was authorized by *Comité de Etica* UIS (CEINCI) in the Acta N° 07 27 April 2018.

Two of us scientifically skinned birds in the field, to prepare voucher specimens; and for the majority of them we obtained and registered the standard biological information (*i.e.*, body mass using a pocket electronic scale, size of the gonads, skull ossification, molt, brood patch, cloacal protuberance, presence of ocular ring, as well as the color of the iris, the bill and the tarsus). For some specimens, a few data were not taken because gonads were not found or data of molt, skull, or brood patch were forgotten to be registered. For some specimens, we preserved in diluted formol the stomach and the gonads. We also collected tissue samples of muscle, liver, and heart for every specimen, which were preserved in ethanol 96 % during the field work and then, after removing ethanol in laboratory, were cryo-preserved in a freezer at -80 °C as part of a new collection (UIS-CT= *Colección de Tejidos del Museo de Historia Natural de la Universidad Industrial de Santander*, Bucaramanga). Once in the bird collection (UIS-AV= *Colección de Aves del Museo de Historia*

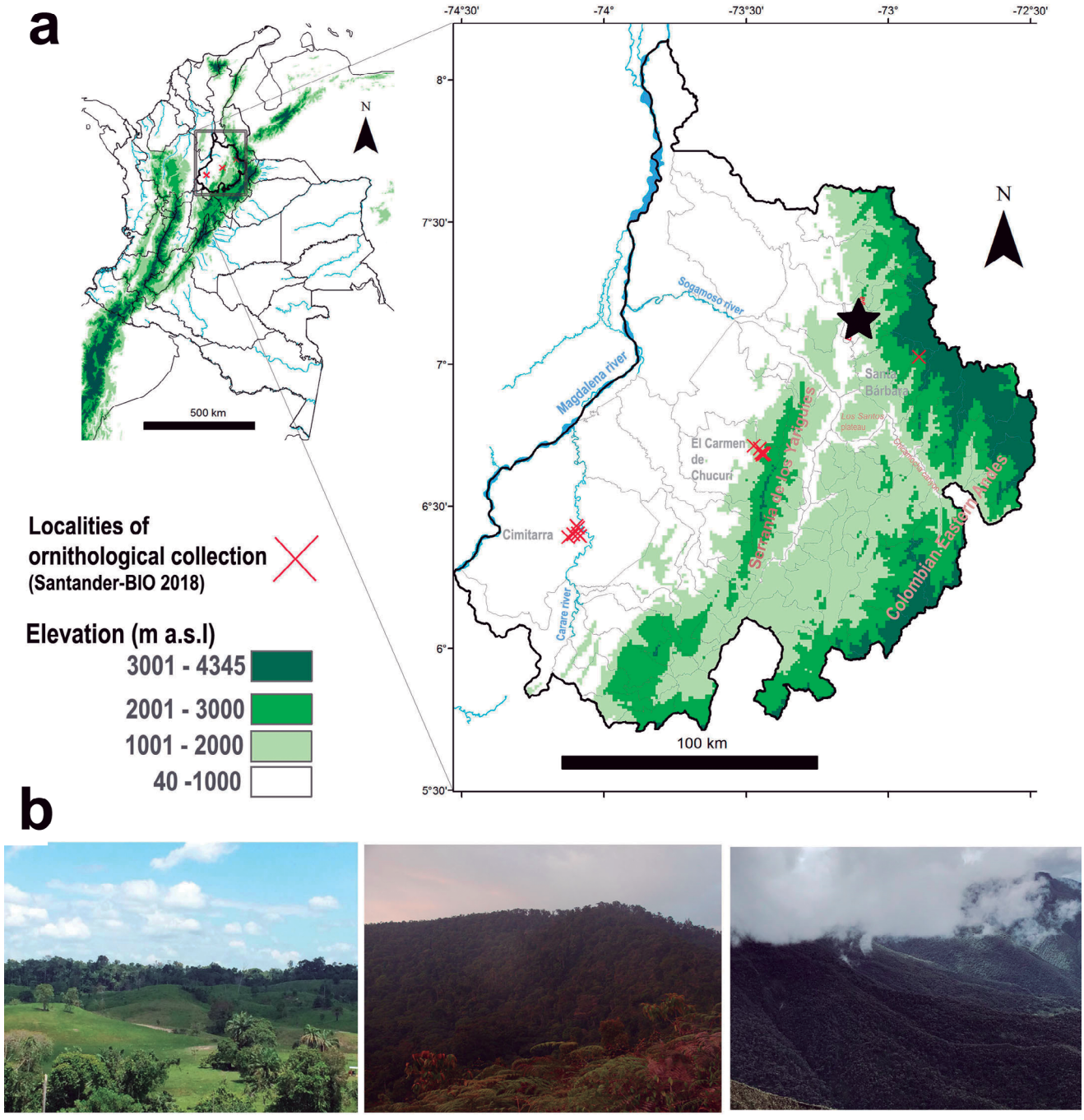

Figure 1: a) Map of Santander department depicting some major orographic accidents and rivers. Municipalities where expeditions were conducted are indicated, as well as the capital city Bucaramanga (black star) The inset shows the place of Santander in Colombia. b) Landscape views of the forests where collections were conducted. From left to right: Cimitarra, El Carmen de Chucurí, and Santa Bárbara.

Natural de la Universidad Industrial de Santander, Bucaramanga) specimens were curated and their data digitalized following a format based on the Darwin Core standard (Biodiversity Information Standards TDWG, 2018). For taxa represented by several voucher specimens, some were cataloged at UIS-AV, and the remaining were exchanged for other specimens with the IAvH. To catalog specimens here, we used the catalog number of UIS-AV for most of them and the field number (consecutive SBIO-number that is attached in a label to each specimen) for the ones that were exchanged with IAvH.

Besides the collection of voucher specimens during the three expeditions, we also obtained occasional records of bird species based on visual and acoustic observations (50 observation hours), to complement our species list (Appendix) and discuss some issues about them. Therefore, these observational records were not included in our main analyses. We followed the taxonomy of Gill and Donsker (2018).

Data Analyses

Bird collection analyses

The capture rate, defined as the number of individuals captured per mist net hour, was calculated for each expedition. To test, if such capture rate was similar among expeditions, we performed a χ^2-test. We acknowledge that for Colombian forests there is quantitative information that collecting using mist nets have a bias in the taxa and sizes of the collected specimens (Stiles and Roselli, 1998; Polanco *et al.*, 2015), but we also consider that our collection series allow a coarse comparison (*i.e.*, species per Family) among the forests visited because the same bias in the collection methods is shared by the three expeditions. To have a picture of the bias in our data, due to the use of mist nets, we used the body masses of the specimens we collected and compared them between specimens collected with mist nets and specimens collected using the airgun. To conduct this comparison, we used a Mann-Whitney U-test to evaluate if the distribution of body masses of the specimens collected by both methods was the same.

Ornithological expeditions in Santander expand for more than two centuries. Therefore, we included the bird series of voucher specimens that we collected during Santander-BIO project in such historical frame to analyze its significance. We conducted a query in online databases through the Global Biodiversity Information Facility (GBIF.org, 2018) using the "advanced search" option. Because we were only interested in avian voucher specimens we filter by "basis of record" = "preserved specimen" and geographically by "country or area" = "Colombia." Such query rendered 214 470 results of avian voucher specimens with information about collection event (*e.g.*, date, collector name, locality, elevation), museum (*e.g.*, biological collection where the specimen is cataloged and its catalog number), and taxonomic information. Such primary data represented Colombian specimens, and then we curated them by geography to obtain only records for Santander. Such geographic curation involved two steps: 1) each locality was revised under the criteria of one of us (DV-E), who has experience in curating geographic information from UIS-AV, and who chose only those records that in principle could belong to Santander; 2) to confirm that the chosen records really belong to Santander, we imported only georeferenced occurrences (4134 occurrences data) in QGIS® software (QGIS Development Team, 2011), using the Santander political boundaries shapefile, and all occurrences falling within such boundaries were considered as an avian voucher specimen record for the Santander department. We also performed an additional query, including "Santander" at the "locality" filter at GBIF, and we obtained 88 data of which only 11 were new. The final list of avian voucher specimens from Santander, Colombia, included 5299 museum specimens.

This list depicts the number of specimens collected per year in Santander. We used this list for two aims: 1) to know the magnitude of the collection of birds by UIS during Santander-Bio expeditions, comparing their numbers with the numbers of specimens per year along the historical ornithological exploration of Santander; and 2) to identify the taxa collected by UIS during Santander-Bio expeditions that are represented by the first time by a voucher specimen for this department. To discuss the novelty of these new voucher specimens for Santander, we also revised the audio records at Xeno-canto Foundation (2018); Macaulay Library (2019), and *Banco de Sonidos Ambientales*-IAvH available through Global Biodiversity Information Facility (GBIF.org, 2018).

Analysis of the monetary costs of collecting voucher specimens

As noted above, we had the aim of quantifying the monetary costs related to the bird specimens obtained. For this, we used the detailed budget approved for Santander-Bio project that includes the costs of materials and payments for services of every activity. To measure the costs involved in bird collection and curation, we calculated three kinds of costs but considering only a fraction of the allocated budget that we estimated was directly related to the collection and curation of bird specimens. First, we calculated the human resources payment by adding the budget allowance for activities related to bird specimens collection and curation such as 1) a fraction of the payment for senior and junior researchers in charge of field and biological collection work, 2) a fraction of the payment for a field assistant, 3) a fraction of payment for UIS students who helped with curational activities at UIS-AV, 4) a fraction of payment for other UIS students who helped with the digitalization of data. Second, we included a percentage of the costs of materials (*i.e.*, mist nets and cryovials). The mentioned budget fraction was between 1/8 and 7/8 of the budget allocated for particular issues (see Table 2), considering that both the payment for human resources and the materials used were assigned to other activities related to the project and not just to obtain and curate the bird specimens. For instance, the total budget allocated to pay a junior researcher (Biologist) was around 23 500 000, but the payment included other activities not related to direct bird collection and curation (*i.e.*, writing reports), and then we estimated the investment in specimens

as 7/8 of such budget. The same was considered for the other human resources payments and the use of material. Third, we added our costs of transport, alimentation, and lodging during expeditions; and such value was considered as the cost of fieldwork logistics. The sum of the three kinds of costs divided by the number of specimens collected is the measure of the total cost of obtaining a bird voucher specimen and their tissues for molecular analyses, during an expedition of UIS in Santander-Bio project, as well as to place these voucher specimens and their tissues in a biological collection with curated and digitalized information ready to be publicly available. The costs were calculated in Colombian pesos (COP) as was the original budget but were converted to US dollars considering a change rate of $3249.75 COP = US$1 US, according to representative market rate from 31/12/2018.

RESULTS

Bird records and voucher specimen collection

We captured 403 bird individuals, of which we collected 300 voucher specimens and their tissues, after a total sampling effort of 1290 mist net hours plus opportunistic collection using airgun (Table 1). These voucher specimens represent 117 species from 30 families and 12 orders (Appendix); the occasional records added 120 species and 19 families (Appendix). Therefore, our dataset includes 237 species from 49 bird families. The families represented by more than ten voucher specimens were: Trochilidae (83 specimens), Tyrannidae (35), Furnariidae (34), Thraupidae (28), Parulidae (16), Emberizidae (15), Thamnophilidae (14), and Pipridae (10). 62 species (53 %) were represented by two or more voucher specimens.

The number of species that we collected was 50, 26, and 49 for the expeditions to El Carmen de Chucurí, Cimitarra, and Santa Barbara, respectively. Eight species (6.8 %) were recorded in more than one expedition (Appendix): Green-fronted Lancebill (*Doryfera ludovicae*), Speckled Hummingbird (*Adelomyia melanogenys*), Olive-striped Flycatcher (*Mionectes olivaceus*), White-breasted Wood-Wren (*Henicorhina leucosticta*), Chestnut-capped Brushfinch (*Arremon brunneinucha*), and Three-striped Warbler (*Basileuterus tristriatus*) collected in Santa Bárbara and El Carmen de Chucurí, as well as Wedge-billed Woodcreeper (*Glyphorynchus spirurus*) and Ochre-bellied Flycatcher (*Mionectes oleagineus*) collected in Santa Barbara and Cimitarra. We obtained observational records of twelve species during one expedition, which were collected in a subsequent expedition (Appendix). The use of the airgun retrieved 13 species (11 %), of which only three species were also collected by mist nets (*i.e.*, Whooping Motmot [*Momotus subrufescens*], Black-chested Jay [*Cyanocorax affinis*], and Blackburnian Warbler [*Setophaga fusca*]). The species observed but not collected were mainly from families of water birds, pigeons, raptors, swifts, and parrots (Appendix). Because of their biology (*i.e.*, size, habitat, foraging strategy, or behavior), such species are difficult to capture using mist nets.

The number of families collected varied among expeditions (Fig. 2), being the expedition to El Carmen de Chucurí, the one providing the largest number (24). There was variation in the number of species collected per family (Fig. 2), but a large proportion of species captured during the three expeditions were from the Tyrannidae and Furnariidae, each one of them representing more than 11 % of the species collected in every expedition. It is noteworthy that Thraupidae represented a large proportion of the species collected in Cimitarra and Santa Barbara (15 to 20 %), and Trochilidae encompassed a large proportion (17 to 20 %) of the species in El Carmen de Chururí and Santa Barbara, but was just represented by one species (Pale-bellied Hermit [*Phaethornis anthophilus*], UIS-AV-2197) in Cimitarra. The capture rate also varied among expeditions ($\chi^2 = 123$, d.f. = 2, $p < 0.05$) being almost one order of magnitude lower in Cimitarra (0.08 individuals per mist net hour) than in the other two expeditions to El Carmen de Chucurí (0.3) and Santa Barbara (0.5).

The comparison of our ornithological collection with the historical list of bird specimens from Santander allowed recognizing that the 300 voucher specimens collected by UIS during Santander-BIO expeditions are the largest series obtained during the last five decades. Since 1965 no more than 250 specimens were collected per year, which marks the Santander-Bio project as an important contribution to the enrichment of the bird fauna collections from Santander. Along with the history of the ornithological collections in Santander, which began around 150 years ago according to GBIF records, there are only three years (1949, 1961 and 1964) where more than 300 voucher specimens were obtained. Such collections corresponded to expeditions conducted by the Smithsonian National Museum of Natural History U.S.A (1949), the Yale Peabody Museum of Natural History U.S.A (1961), the Museum of Vertebrate Zoology UCLA at Berkeley U.S.A (1964), and the Los Angeles County Natural History Museum U.S.A (1961 and 1964). The historical list of Santander voucher specimens also allowed identifying that 60 % of them are housed in foreign biological collections. It is only since 1970 that the Colombian biological collections began to be relevant in the documentation of bird diversity from Santander; currently, the two institutions with more voucher specimen records of Santander birds (GBIF.org, 2018) are UIS-AV at Bucaramanga and IAvH-A at Villa de Leyva (previously INDERENA). Comparing the historical list of voucher specimens from Santander with our data, we found that 16 species collected by UIS during Santander-BIO expeditions were collected for the first time by a voucher specimen for Santander (Appendix).

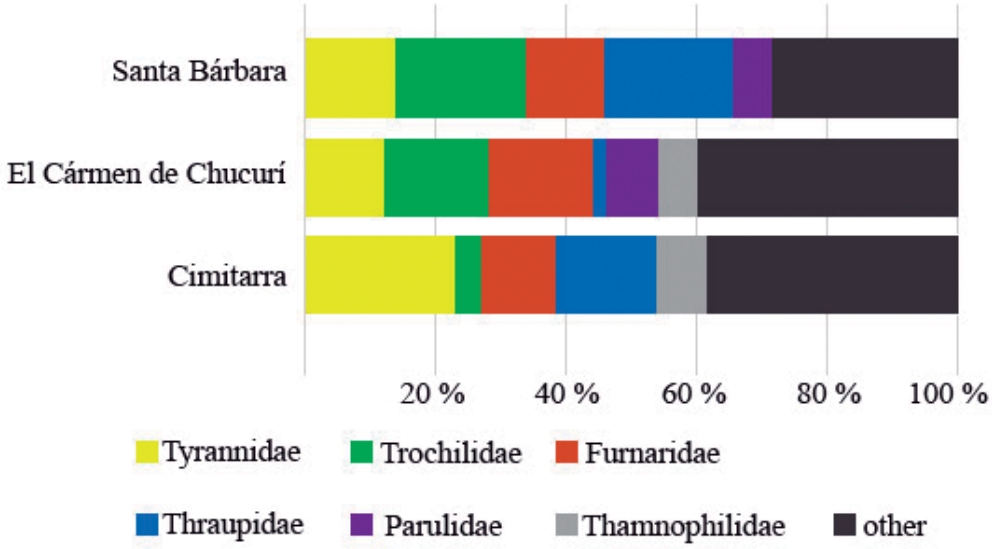

Figure 2. The proportion of the number of species per Family collected during the three expeditions of Santander BIO 2018, Santander, Colombia. The category "other" includes families represented by less than seven species.

Biological information of the specimens

For 271 specimens, we obtained information about their sex by examining gonads. Of them, 124 were females and 147 were males. We found specimens of eight species (excluding hummingbirds that showed no ossification related to age) with skull ossification ≥ 50 %, relatively large gonads, and brood patch. We interpreted the occurrence of these three features like a signal of breeding condition despite the lack of complete ossification. Among the hummingbirds, we found six species that also could be in breeding condition, considering their gonads size. For 156 specimens (excluding hummingbirds) we obtained data on skull ossification. Of these specimens, 33 from 21 species showed ossification < 50 %, and we considered them as juveniles or immature. We interpreted the presence of these individuals as a signal of the occurrence of a recent reproductive event of those species.

Body mass ranged between 2.5 gr (White-booted Racket-tail [*Ocreatus underwoodii*], UIS-AV-2171) and 1300 gr (Wattled Guan [*Aburria aburri*], UIS-AV-2193), with a mean of 36.3 gr (median = 11.2 gr). The mean of the body masses of specimens collected by mist nets was 24.8 gr while this value for specimens collected using airgun was 143.5 gr. The result of the Mann-Whitney U test indicates that the centrality of the body masses of the specimens collected by both methods was statistically different ($U = 361$; $z = -5.4$; $p < 0.005$), indicating that mist nets, as was expected, captured species of lower body masses than the ones collected using airgun.

The monetary cost of collecting and cataloging voucher specimens

The monetary costs for collecting and cataloging the 300 bird specimens, with associated tissue samples, and to digitalize their data in a biological collection by UIS are presented in Table 2. Such cost was a total of US$18 110 ($58 852 937 COP). The larger costs were for payment of human resources, which represented around 63 % of the total cost of collecting the complete series of birds. Logistic, which involves activities supporting the scientific fieldwork, was the second issue regarding the costs, representing around 32 % of the total cost, and materials represented only 5 % of the cost. Therefore, the cost of obtaining one Colombian bird specimen during a regional expedition, like the ones conducted by UIS during the Santander-BIO project, and to catalog it in a biological collection (besides its tissue sample) digitalizing its data is ~ $60.4 US dollars ($196 176 COP).

DISCUSSION

Historical ornithological expeditions in Colombia conducted by foreign researchers during the end of 1800's and beginnings of the 1900's provided thousands of specimens and hundreds of taxa records (*e.g.*, Allen, 1900; Chapman, 1917; Friedmann, 1947), indicating that the country was one of the richest around the World. The current recognition of the Colombian bird fauna as the richest one is ultimately based on voucher specimens. The basic documentation of Colombian avian biodiversity has continued through collection during some expeditions and by the description of several new species, with a mean of one new bird species per year since 1990 (Córdoba-Córdoba, 2009; Arbeláez-Cortés, 2013a).

During the last decades, several ornithological expeditions have documented bird biodiversity in different regions of Colombia, but some of these publications

Table 1. Expeditions of Santander-Bio. Geographic information and sampling effort are indicated for each locality where bird voucher specimens were collected during 2018 in three municipalities of Santander.

Expedition	Locality	Coordinates	Elevation (m a.s.l)	Sampling effort	Captured individuals	Collected specimens
El Carmen de Chucurí (17 february - 3 march 2018)	1a) Colombia, Santander, Municipio El Carmen de Chucurí, Vereda La Bodega, Filo de Manchurrias, finca Buenos Aires a 8km en linea recta EpS de la cabecera municipal del Carmen de Chucurí, camino de personas (Trocha) al sur de la finca Buenos Aires.	6° 40' 50,7" N ; 73° 26' 29,9" W	1850	500 h / mistnet	148	110
	1b) Colombia, Santander, Municipio El Carmen de Chucurí, Vereda La Bodega, finca San Francisco	6° 42' 49,8" N ; 73° 28' 19,9" W	1395			
	1c) Colombia, Santander, Municipio El Carmen de Chucurí, Vereda La Bodega, Filo de Manchurrias, finca Buenos Aires a 8km en linea recta EpS de la cabecera municipal del Carmen de Chucurí, Camino de herradura al oeste de la finca Buenos Aires.	6° 41' 15" N ; 73° 26' 22,78" W	1734			
	idem 1a	6° 40' 50,6799" N; 73° 26' 29,86" W	1850	oportunistic collection using airgun	4	4
	1d) Colombia, Santander, Municipio El Carmen de Chucurí, Vereda La Bodega, finca La Bodega	6° 41' 16,045" N ; 73° 26' 43,37" W	1534	oportunistic collection using airgun	2	2
	1e) Colombia, Santander, Municipio El Carmen de Chucurí, Vereda La Bodega, quebrada San Guillerma, abajo del Filo de Manchurrias	6° 41' 4,2" N ; 73° 26' 9,2" W	1608	oportunistic collection using airgun	1	1
	1f) Colombia, Santander, Municipio El Carmen de Chucurí, Vereda La Bodega, Filo de Manchurrias, finca Buenos Aires a 8km en linea recta EpS de la cabecera municipal del Carmen de Chucurí, Casa de la finca Buenos Aires	6° 41' 13,7176" N ; 73° 26' 27,63" W	1695	oportunistic collection using airgun	1	1
	1g) Colombia, Santander, Municipio El Carmen de Churcurí, Vereda La Bodega. En inmediaciones de la Carretera hacia San Vicente de Cuchurí.	6° 42' 9,12" N ; 73° 27' 5,64" W	1401	Salvaged specimen	1	1
Cimitarra (7 - 21 july 2018)	2a) Colombia, Santander, Cimitarra, Bosque frente a finca Aguas Claras, a 20 minutos en carro desde finca El Dorado, Vereda El Tigre, 18 km lineales NOpO del casco urbano de Cimitarra.	6° 24' 15,1"N ; 74° 5' 24,8" W	166	382 h/mistnet	31	29
	2b) Colombia, Santander, Cimitarra, Finca Caño Dorado, Vereda El Tigre, a 20 km lineales NOpO del casco urbano de Cimitarra.	6° 25' 27,5" N ; 74°5'25,2' 'W	137			

(*Continued*)

Table 1. Expeditions of Santander-Bio. Geographic information and sampling effort are indicated for each locality where bird voucher specimens were collected during 2018 in three municipalities of Santander.

Expedition	Locality	Coordinates	Elevation (m a.s.l)	Sampling effort	Captured individuals	Collected specimens
Cimitarra (7 - 21 july 2018)	2c) Colombia, Santander, Bosque La Raya, Vereda El Tigre, 21 km lineales ONO del casco urbano de Cimitarra.	6° 23' 29" N ; 74° 7' 30" W	167			
	2d) Colombia, Santander, Cimitarra, Reserva forestal de la Finca Caño Dorado, Vereda El Tigre, a 20,7 km lineales NOpO del casco urbano de Cimitarra	6° 25' 54,8 ''N ; 74° 5' 45" W	134			
	idem 2b	6° 25' 27,5" N ; 74°5'25,2" W	137	oportunistic collection using airgun	1	1
	idem 2c	6° 23' 29" N ; 74° 7' 30" W	167	oportunistic collection using airgun	1	1
	idem 2d	6° 25' 54,8 ''N ; 74° 5' 45" W	134	oportunistic collection using airgun	1	1
	2e) Colombia, Santander, Cimitarra, Caño, Caño Dorado, Vereda El Tigre, a 17,2 km lineales NOpO del casco urbano de Cimitarra	6° 23' 44,3" N ; 74° 4' 57,8" W	121	oportunistic collection using airgun	1	1
	2f) Colombia, Santander, Vereda El Tigre, alrededores de la tienda "El Tuvi", aprox. 19 km lineales NoPO del casco urbano de Cimitarra.	6° 24' 5,75" N ; 74° 6' 25,76" W	126	Salvaged specimen	1	1
Santa Bárbara (6 -20 August 2018)	3) Colombia, Santander, Santa Bárbara, Vereda Esparta, Camino (Trocha) Chitanos arriba de Finca La Arrinconada, entre 5 y 6 km lineales NNE del casco urbano de Santa Bárbara	7° 1' 34" N ; 72° 53' 31" W	2850	408 h/mistnet	210	143

report occasional collection of voucher specimens. For instance: incidentally dead during captures in mist nets or specimens representing taxa considered noteworthy because represents range extensions (Bohorquez, 2002; Donegan *et al.*, 2007; Donegan *et al.*, 2010; Avendaño *et al.*, 2018a; b). One of these works included a large series of specimens for Santander (Donegan *et al.*, 2010). There are also publications documenting results of systematic collection of bird specimens (Haffer, 1986; Stiles and Bohórquez, 2000; Alvarez *et al.*, 2003; Cuervo *et al.*, 2008a; b ; López-Ordóñez *et al.*, 2013; Stiles and Beckers, 2016; Renjifo *et al.*, 2017; Stiles and Naranjo, 2017) for several departments (*i.e.*, Antioquia, Boyacá, Caquetá, Cauca, Cesar, Chocó, Guainia, Guaviare, and Nariño), but not for Santander. The results of these publications indicated the collection of 25 to 287 specimens, representing between 25 and 150 species. Therefore, both the number of specimens and species we reported here during Santander-BIO expeditions are among the larger for recent ornithological expeditions in Colombia. As we noted above, the voucher specimen series obtained by UIS during Santander-Bio is one of the larger ones of the historical ornithological collections in Santander.

In Santander, there are several localities with ornithological records (Riaño, 2017), and there are records for around 840 potential bird species (Rondón, 2017). In this context, the total number of species we presented for 14 localities, at three municipalities, represented 28.2 % for those recorded in the department of Santander. Considering only records based on voucher specimens, we reported almost 14 % of the total number of the potential bird species for Santander. However, the number of Santander bird species represented by vouchered specimens in biological collections probably is around 650 (GBIF.org, 2018), and our collection series is ~ 20 % of such figure. We report for the first time a voucher specimen for 16 species in Santander. Among them we highlight the records of four species:

Table 2. Costs of collecting and curating 300 bird specimens during expeditions of Santander-Bio. Costs are in Colombian pesos. The activities related with collecting and curation includes tissue samples and data digitalization. The "fraction" approximates the proportion of the specific budget invested for services or materials related directly with bird collection and curation.

	Costs involved in direct collection and curation of 300 bird specimens (Colombian pesos)	Fraction of the budget allocated for activity that was invested in direct collection and curation
Human resources		
Senior researcher (Ph.D)	8 987 264	1/8
Junior researcher (Biologist)	20 656 076	7/8
Auxiliars for curatorial activities (undergraduate students)	6 455 024	2/5
Field work assistants (basic academic studies, but with fieldwork expertise)	1 161 904	1/5
Materials		
Use of mistnets, cryiovials, and materials for scientific skinning	2 657 022	1/5
Logistic		
Personal and equipment transportation, alimentation, and lodging	18 935 647	Complete
Total cost of 300 bird specimens	58 852 937	
Total cost per bird specimen	196 176 (~US$60.4)	

- The Red-legged Tinamou (*Crypturellus erythropus*) is a tinamou with a wide geographical range found in lowlands from Northern Colombia to Brazil, but it could be locally uncommon at some places (Hilty and Brown, 1986; Hilty, 2003; Restall *et al.*, 2006). Our voucher specimen is 230 Km from the closest Colombian voucher specimen from "Ayacucho, Cesar" (USNM 372312), and considering audio records this species has a few in Cesar (*e.g.*, Xeno-canto, 2018, 45340, 45342) and to the North at La Guajira (*e.g.* Xeno-canto, 2018, 92405, 92576).
- The Cinnamon Screech Owl (*Megascops petersoni*) is a scarce owl that inhabits inside forests and is poorly known in Peru, Ecuador, and Colombia (Ridgely and Greenfield, 2001; Schulenberg *et al.*, 2007; Cuervo *et al.*, 2008b). Our record (UIS-AV-2180) from El Carmen de Chucurí is one of the few voucher specimens for Colombia. Cuervo *et al.* (2008b) reported the first one in Anorí, Antioquia (ICN-34377), and commented on the existence of an old "Bogotá" skin. We also found, at UIS-AV, an uncatalogued specimen of this taxon without a label and from unknown origin, and IAvH-A reported another specimen from Cueva de Los Guacharos, Huila (IAvH-A 12391). The locality of UIS-AV-2180 is 190 Km from the nearest locality, but very close to an audio record (Xeno-canto, 2018, 143842) of this species from San Vicente de Chucurí, Santander.
- The Saffron-headed Parrot (*Pyrilia pyrilia*) is an uncommon local parrot in Colombia, which inhabits humid lowland forests (Hilty and Brown, 1986; Restall *et al.*, 2006). The localities of UIS-AV-1944 and IAvH-A (SBIO-57) are 120 Km from the nearest locality with a voucher specimen: Puerto Berrio, Antioquia (AMNH 154431), and farther from audio records in Antioquia (*e.g.*, BSA 19070, 30144).
- The Chestnut-crowned Gnateater (*Conopophaga castaneiceps*) is a local uncommon species that inhabits the undergrowth of montane forests in the Andes, from Colombia to Peru (Ridgely and Tudor, 1994). The locality of UIS-AV-1900, 2187, and IAvH-A (SBIO-62) is 138 Km from the nearest locality with a voucher specimen: Otanche, Boyacá (ICN 32833), but very close to an audio record (Xeno-canto, 2018, 401285) of this species from San Vicente de Chucurí, Santander.

Other relevant records were those for geographically restricted taxa or species of conservation concern such as Black Inca (*Coeligena prunellei*), White-mantled Barbet (*Capito hypoleucus*), Parker's Antbird *(Cercomacroides parkeri),* Ochre-breasted Antpitta *(Grallaricula flavirostris),* and Sooty Ant-Tanager *(Habia gutturalis)* (Appendix).

Reproductive periods of Neotropical birds expand several months, which are related to the abundance of food resources but are not well defined for several species (Echeverry-Galvis and Córdoba-Córdoba, 2008). We collected juveniles and adults with physical indication of breeding condition, allowing us to determine that 70 – 80 % of the species from Cimitarra and Santa Barbara agreed

with the breeding months previously reported, contrasting with El Carmen de Chucurí where only 50 % of the species agreed with published breeding periods (Hilty and Brown, 1986; Fjeldså and Krabbe, 1990; Del Hoyo *et al.*, 2003). Collecting detailed breeding data (Foster, 1975; Echeverry-Galvis and Córdoba-Córdoba, 2008) must be considered in further expeditions aimed to obtain voucher specimens of Colombian birds to enhance the biological knowledge.

Regarding the mist net capture rate calculated from the data available in some publications for Colombian ecosystems (Stiles and Roselli, 1998; Stiles and Bohórquez, 2000; Polanco *et al.*, 2015; Stiles and Beckers, 2016; Renjifo *et al.*, 2017; Stiles and Naranjo, 2017; Córdoba-Córdoba and Sierra, 2018), we found results that indicate a rate between 0.14 and 0.77 individuals captured per mist net hour (mean = 0.37, n = 7). Therefore, the capture rate we obtained during our expeditions to Carmen de Chucurí and Santa Barbara is within this range; however, the capture rate for Cimitarra (0.08) is very low and represents an issue for further study.

We acknowledge the bias of documenting bird diversity using only mist nets to document the whole bird fauna of a locality because they usually represent between 50 and 75 % of the species (Stiles and Roselli, 1998; Polanco *et al.*, 2015). Occasional observational records allow reporting a large proportion of species that are not easily captured by mist nets. Besides, for a montane forest in eastern Colombian Andes small birds (< 50 gr) are overrepresented in mist net captures (Stiles and Roselli, 1998). Here we obtained a similar result and found that collecting using airgun added species of larger sizes to the voucher specimen series. The use or airguns has been implemented in other expeditions in Colombia (Stiles and Beckers, 2016; Renjifo *et al.*, 2017; Avendaño *et al.*, 2018a), and we consider that their use, by qualified personnel, during ornithological expeditions can be implemented in further expeditions to optimize the documentation of bird taxa through voucher specimens.

Regarding the monetary costs published for the collection of voucher specimens, we found that one specimen costs between $17.8 and $767 US dollars for regional expeditions in other countries (Yates, 1985; Blackmore *et al.*, 1997; Mann, 1997; Bradley *et al.*, 2012; Baker *et al.*, 2014; Bradley *et al.*, 2014). The lower and higher costs are reported by Bradley *et al*. (2014), who measured monetary investment on mammals collected during 50 regional field trips. These authors included costs related to logistic and human resources services, but they did not include costs of materials. All reviewed studies reported costs for mammal or herbarium collections, and most of them calculated a mean of costs from multiple expeditions for several years. There is ample variation among different expeditions of the same institution (Bradley *et al.*, 2012). We did not find published information on costs of bird collection, but the cost we calculated is within the range reported for mammals and plants. Institutions can check the performance of projects aimed at documenting biodiversity through voucher specimens by asking for estimation costs per specimen. Besides, these institutions and the government must consider these costs as an investment in scientific capital because these voucher specimens will render biological information for decades, or centuries, returning a large value in the form of scientific knowledge about the region or the country (Yates, 1985; Arbeláez-Cortés *et al.*, 2017).

At this point, it is necessary to consider some issues regarding two possible ways to lowering collection costs. If we had collected the 403 bird individuals captured during the three expeditions, the cost per specimen could have decreased a 25 %. However, the kind and number of specimens collected per day was a tradeoff between the scientific relevance and the number of specimens that two of us (DV-E and EA-C) were able to process properly. For instance, this was the reason why we released a migrant species we captured in Carmen de Chucurí (*i.e.*, we considered of more scientific relevance the resident birds captured that day). It is obvious that a larger series of specimens collected can decrease the costs per specimen, but researchers must always take rapid decisions in the field on what material to collect considering both scientific value and logistic issues. Probably, specimen numbers could be increased in further projects by including students as part of expeditions. It is because students are less costly as human resources and can increase the number of specimens processed per day. However, in the case of Santander-BIO project, students cannot participate in fieldwork but contributed to curatorial activities at UIS-AV. Besides, proper scientific skinning of birds seems to be a scarce competence among Colombian biology students, making it necessary to invest time to teach them.

Another issue that is necessary to comment on is that after collecting, curating, and cataloging specimens at UIS-AV, there are other costs involved in storing such material in the long term. For instance, Blackmore *et al*. (1997) consider such cost in their valuation of collecting (or obtaining specimens by other methods), curating, and storing material at the London Natural History Museum. We did not have a measure of such post-curational costs at UIS-AV, but they could be calculated considering three issues: 1) cost of mobiliary for storing specimens, 2) cost of the area (*i.e.*, appropriate facilities) where UIS-AV is placed, and 3) costs of services, including scientific curation (usually as time of a curator and auxiliaries), costs of fumigate the collection, repair of some equipment, and electricity associated with the functioning of equipment for collection maintenance. The cost number 2 is difficult to calculate but could be approximated by costs per m^2 for rents (*i.e.*, per year) or construction of habitational spaces in the same city and near the collection. The costs per specimen in this case also will diminish while the number of cataloged specimen's increases. Therefore, maintaining an active collection of

specimens is a way to optimize the resources allocated to science by institutions and governments.

CONCLUSIONS

We conclude that it is possible to quantify the costs for the collection and curation of scientific specimens, considering the budget directly assigned to these activities. However, we cannot give a precise protocol to measure the cost of a specimen in other expeditions, but we highlight that any calculation of such cost must consider, besides the logistic costs of fieldwork, the human resources costs associated with time invested in direct collecting and curatorial work. The bird specimens obtained in Santander-BIO expeditions rendered the basic information of the birds inhabiting three ecosystems of this Colombian region, but also will allow further studies (*e.g.*, analyses of genetic and phenotypic variation). Therefore, the costs involved in obtaining such material must be considered as an investment in scientific capital, and not as expenditure. We also conclude that voucher specimen collection based on mist nets can be complemented using airguns, or even low caliber shotguns, to have a representative series of the local avifauna. Finally, we recommend to biologists to optimize monetary resources allocated by the government to explore Colombian biodiversity developing, or improving, skills (*e.g.*, skinning, proper capture and manipulation of birds in mist nets, proper sampling and storing of tissues for molecular analyses) which allow collecting large series of voucher specimens to fill scientific knowledge gaps, which will allow having a clear picture of the country biota.

ACKNOWLEDGMENTS

This manuscript is a product of the project "*Investigación de la biodiversidad y los servicios ecosistémicos para la gestión integral del territorio – descubriendo los ecosistemas estratégicos para el fortalecimiento de la gobernanza en el departamento de Santander* (Santander-BIO)", financed by funds from *Sistema General de Regalias de la República de Colombia*. We want to thank *Gobernación de Santander* for gesturing resources for this project and their supervision and advise of administrative issues. We also thank V.H. Serrano, A. Gutierrez, and E. Sepulveda, for logistic support during fieldwork. Special recognition to R. Ramirez (El Carmen de Chucurí), J. A. Jaramillo (Cimitarra), and R. Jaimes (Santa Bárbara) for hospitality and for kindly allowing us to conduct field work in their properties. A.M. Cuervo and J.E Avendaño confirmed or corrected, the taxonomic identification of some voucher specimens. Three anonymous reviewers and D. Santiago-Alarcón made valuable comments on previous versions of this manuscript, which improved the quality of the paper.

CONFLICT OF INTEREST

The author declares that there is no conflict of interests

REFERENCES

Alvarez M, Umaña AM, Mejia GD, Cajiao J, von Hildebrand P *et al.* Aves del parque nacional Serrania de Chiribiqute, Amazonia-provincia de La Guayana, Colombia. Biota Colomb. 2003;4(1):49-63. Doi: https://doi.org/10.21068/bc.v4i1.123

Allen JA. List of birds collected in the District of Santa Marta, Colombia, by Mr. Herbert H. Smith. Bull Am Mus Nat Hist. 1900;13:117-184.

Arbeláez-Cortés E. Describiendo especies: Un panorama de la biodiversidad colombiana en el ámbito mundial. Acta Biolo Colomb. 2013a;18(1):165-178.

Arbeláez-Cortés E. Knowledge of Colombian biodiversity: published and indexed. Biodivers. Conserv. 2013b;22(12):2875-2906. Doi: https://doi.org/10.1007/s10531-013-0560-y

Arbeláez-Cortés E, Torres MF, López-Álvarez D, Palacio-Mejía JD, Mendoza ÁM, *et al.* Colombian frozen biodiversity: 16 years of the tissue collection of the Humboldt Institute. Acta Biolo Colomb. 2015;20(2):163-173. Doi: https://doi.org/10.15446/abc.v20n2.47102

Arbeláez-Cortés E, Acosta-Galvis AR, DoNascimiento C, Espitia-Reina D, González-Alvarado, A *et al.* Knowledge linked to museum specimen vouchers: measuring scientific production from a major biological collection in Colombia. Scientometrics. 2017;112(3):1323–1341. Doi: https://doi.org/10.1007/s11192-017-2461-4

Avendaño JE. Una breve historia de la ornitología colombiana y sus inicios en Santander. In: Universidad Industrial de Santander, editor(s). Colores al vuelo. Bucaramanga: División de publicaciones UIS.2017. p 27-48.

Avendaño JE, Arbeláez-Cortés E, Cadena CD. On the importance of geographic and taxonomic sampling in phylogeography: A reevaluation of diversification and species limits in a Neotropical thrush (Aves, Turdidae). Mol Phylogenet Evol. 2017a;111:87-97. Doi: https://doi.org/10.1016/j.ympev.2017.03.020

Avendaño JE, Bohórquez CI, Rosselli L, Arzuza-Buelvas D, Estela FA, *et al.* Lista de chequeo de las aves de Colombia: Una síntesis del estado del conocimiento desde Hilty & Brown (1986) Ornitol Colomb. 2017b;16(eA01):1-83.

Avendaño JE, López-O JP, Laverde-R O. Bird diversity of the Cúcuta valley (Colombia) and biogeographical affinities with dry forest avifaunas of northern South America. Wilson J Ornithol. 2018a;130(1):213–223. Doi: https://doi.org/10.1676/16-016.1

Avendaño JE, López-O JP, Laverde-R O. New bird records from the arid Cúcuta Valley, north-east Colombia. Bull Br Ornithol Club. 2018b;138(3):230-237. Doi: https://doi.org/10.25226/bboc.v138i3.2018.a3

Ayala L, Murcia MA, Barriga JC, García F, Garcia H. Expediciones científicas nacionales. In: Moreno LA, Rueda C, Andrade GI, editor(s). Biodiversidad 2017: Estado y tendencias de la biodiversidad continental de Colombia. Bogotá: Instituto de investigacion de recursos biologicos Alexander von Humboldt. 2018. p 83.

Baker RJ, Bradley LC, Garner HJ, Bradley RD. "Door to drawer" costs of curation, installation, documentation, databasing, and long-term care of mammal voucher specimens in natural history collections. Occas Pap Tex Tech Univ Mus. 2014;(323):1-15.

Biodiversity Information Standards TDWG. Darwin Core. 2018. Available in: https://dwc.tdwg.org/

Blackmore S, Donlon N, Watson E. Calculating the financial value of systematic biology collections. In: Nudds JR, Pettitt CW, editor(s). The Value and Valuation of Natural Science Collections. London: The Geological Society.1997. p 279.

Bohorquez CI. La avifauna de la vertiente oriental de los Andes de Colombia. Tres evaluaciones en elevacion subtropical. Rev Acad Colomb Cienc Exactas Fis Nat. 2002;26(100):419-442.

Bradley RD, Bradley LC, Garner HJ, Baker RJ. Cost of collecting and preparing mammal voucher specimens for natural history collections. Occas Pap Tex Tech Univ Mus. 2012;(313):1-13.

Bradley RD, Bradley LC, Heath J. Garner, Baker RJ. Assessing the value of natural history collections and addressing issues regarding long-term growth and care. BioScience. 2014;64(12):1150-1158. Doi: https://doi.org/10.1093/biosci/biu166

Caycedo-Rosales P, Laverde O, Arbeláez-Cortés E. Nuevas especies de aves en Colombia: Uso de estudios multicriterio para su descubrimiento (Ficha 105). In: Bello JC, Báez M, Gómez MF, Orrego O, Nägele L, editor(s). Biodiversidad 2014: Estado y tendencias de la biodiversidad continental de Colombia. Bogotá: Instituto de investigacion de recursos biologicos Alexander von Humboldt. 2014. pp. 40-41

Clemann N, Rowe KMC, Rowe KC, Raadik T, Gomon M, *et al.* Value and impacts of collecting vertebrate voucher specimens, with guidelines for ethical collection. Mem Mus Vic. 2014;72:141-151.

Córdoba-Córdoba S. Historia de la ornitología colombiana: sus colecciones científicas, investigadores y asociaciones. Boletín SAO. 2009;19(12):1-26.

Córdoba-Córdoba S, Sierra S. Nuevos registros y ampliación de distribución de aves en la vertiente occidental, Cordillera Oriental, Santander, Colombia. Acta Biolo Colomb. 2018;23(3):274-285. Doi: http://dx.doi.org/10.15446/abc.v23n3.69008

Cuervo AM, Cadena CD, Parra JL. Seguir colectando aves en Colombia es imprescindible: un llamado a fortalecer las colecciones ornitológicas. Ornitol Colomb. 2006;(4):51-58.

Cuervo AM, Pulgarín PC, Calderón-F D, Ochoa-Quintero JM, Delgado-V CA *et al.* Avifauna of the northern Cordillera Central of the Andes, Colombia. Ornitol Neotrop. 2008a;19:495–515.

Cuervo AM, Pulgarín PC, Calderón D. New distributional bird data from the Cordillera Central of the Colombian Andes, with implications for the biogeography of northwestern South America. Condor. 2008b;110(3):526–537. Doi: https://doi.org/10.1525/cond.2008.8555

Chapman FM. The distribution of bird-life in Colombia: a contribution to a biological survey of South America. Bull Am Mus Nat Hist. 1917;36:1-728.

Riaño D (Compilador). Documentaves, Bibliografía Ornitológica de Colombia. [28 November 2018]. 2017. Available in: https://documentaves.com.co/

Del Hoyo J, Elliot A, Christie DA. Handbook of the Birds of the World: Broadbills to Tapaculos. Barcelona: Lynx Edicions; 2003. 845 p.

Donegan TM, E.Avendaño-C J, Briceño-L ER, Huertas B. Range extensions, taxonomic and ecological notes from Serranía de los Yariguíes, Colombia's new national park. Bull Br Ornithol Club. 2007;127(3):172-213

Donegan TM, Avendaño JE, Briceño-L. ER, Luna JC, Roa C, *et al.* Aves de la Serranía de los Yariguíes y tierras bajas circundantes, Santander, Colombia. Cotinga. 2010;32:72-89.

Donegan T, Verhelst JC, Ellery T, Cortés-Herrera O, Salaman P. Revision of the status of bird species occurring or reported in Colombia 2016 and assessment of BirdLife International's new parrot taxonomy. Conserv Colomb. 2016;(24):12-36.

Echeverry-Galvis MÁ, Córdoba-Córdoba S. Una visión general de la reproducción y muda de aves en el neotrópico. Ornitol Neotrop. 2008;19(Suppl.):197-205.

Fjeldså J, Krabbe N. Birds of the High Andes. Copenhagen: Zoological Museum, University of Copenhagen and Apollo Books; 1990. 876 p.

Foster MS. The overlap of molting and breeding in some tropical birds. Condor. 1975;77:304-314.

Friedmann H. Colombian birds collected by brother Niceforo. Caldasia. 1947;4(20):471-494.

Gill F, Donsker D. IOC World Bird Names v 8.2. [30 September 2018]. 2018. Available in: http://www.worldbirdnames.org

GBIF.org. GBIF Occurrence Download [24 September 2018]. Doi: https://doi.org/10.15468/dl.23uga7

Gobernación de Santander. Plan de desarrollo departamental: Santander nos une. Bucaramanga, Colombia; 2016.

Haffer J. On the avifauna of the upper Patia valley, southwestern Colombia. Caldasia. 1986;15(71-75):533-553.

Hilty SL, Brown WL. A guide to the birds of Colombia. New Jersey: Princeton University Press; 1986. 996 p.

Hilty SL. Birds of Venezuela. New Jersey: Princeton University Press; 2003. 776 p.

Holmes MW, Hammond TT, Wogan GOU, Walsh RE, LaBarbera K, *et al*. Natural history collections as windows on evolutionary processes. Mol Ecol. 2016;25(4):864-881. Doi: https://doi.org/10.1111/mec.13529

IDEAM. Atlas climatológico de Colombia [24 November 2018]. 2015. Available in: http://atlas.ideam.gov.co/visorAtlasClimatologico.html Según la clasificación de formaciones vegetales del mundo de L. R. Holdridge República de Colombia [Mapa ecológico]. Ministerio de Hacienda y Crédito Público, Instituto Geográfico Agustín Codazzi, Subdireccion agrológica; 1976.

Izquierdo E, Naranjo LG, Losada-Prado S, Arbeláez-Cortés E. Aves. In: Trujillo F, Lasso CA, editor(s). Serie fauna silvestre Neotropical IV. Biodiversidad del río Bita, Vichada, Colombia. Bogotá: Instituto de investigacion de recursos biologicos Alexander von Humboldt. 2017. pp. 277-291

Lavoie C. Biological collections in an ever-changing world: Herbaria as tools for biogeographical and environmental studies. Perspect Plant Ecol Evol Syst. 2013;15(1):68-76. Doi: http://dx.doi.org/10.1016/j.ppees.2012.10.002

López-Ordóñez JP, Cortés-Herrera JO, Paez-Ortíz CA, González-Rojas MF. Nuevos registros y comentarios sobre la distribución de algunas especies de aves en los Andes Occidentales de Colombia. Ornitol Colomb. 2013;(13):21-33.

Macaulay Library at the Cornell Lab of Ornithology. [3 April 2019]. 2019. Available in: https://www.macaulaylibrary.org/how-to/media-attribution/

Mann D. The economics of botanical collections. In: Nudds JR, Pettitt CW, editor(s). The value and valuation of natural science collections. London: The Geological Society.1997. p 279.

Nudds JR, Pettitt CW. The value and valuation of natural science collections. London Geological Society of London; 1997. 279 p.

Paknia O, Rajaei Sh. H, Koch A. Lack of well-maintained natural history collections and taxonomists in megadiverse developing countries hampers global biodiversity exploration. Org Divers Evol. 2015;15(3):619-629. Doi: https://doi.org/10.1007/s13127-015-0202-1

Polanco JM, Duque AO, Giraldo DA, Granada JS, Marín OH. Efectividad de las redes de niebla para determinar la riqueza de aves en un bosque montano de los andes centrales (Salento, Quindío, Colombia). Rev Invs Universidad Quindío. 2015;27(1):75-88.

QGIS Development Team. QGIS Geographic Information System. v 2.18 ed: OSGeo. 2011.

Renjifo LM, Repizo A, Ruiz-Ovalle JM, Ocampo S, Avendaño JE. New bird distributional data from Cerro Tacarcuna, with implications for conservation in the Darién highlands of Colombia. Bull Br Ornithol Club. 2017;137(1):46-65. Doi: https://doi.org/10.25226/bboc.v137i1.2017.a7

Restall R, Rodner C, Lentino M. Birds of Northern South America: An identification guide. New Haven: Yale University Press; 2006. 656 p.

Ridgely RS, Tudor G. The birds of South America Volume II. Austin: University of Texas Press; 1994. 814 p.

Ridgely RS, Greenfield PJ. The birds of Ecuador. Cornell University Press; 2001. 740 p.

Rondón F. Aves en ecosistemas de Santander. In: Universidad Industrial de Santander, editor(s). Colores al Vuelo. Bucaramanga: División de publicaciones UIS.2017. p 51-167.

Schulenberg TS, Stotz DF, Lane DF, O'Neill JP, III TAP. Birds of Peru. New Jersey: Princeton University Press; 2007. 664 p.

Secretaría de planeación de Santander, Universidad Industrial de Santander. Formulación de la visión prospectiva de Santander 2019-2030. Bucaramanga, Colombia; 2011. 229 p.

Secretaría de planeación de Santander. Lineamientos y directrices de ordenamiento territorial del departamento de Santander. Bucaramanga, Colombia; 2014. 323 p.

Sistema de Información sobre Biodiversidad de Colombia [SiB-Colombia]. Biodiversidad en cifras. [27 November 2018]. 2018. Available in: https://sibcolombia.net/actualidad/biodiversidad-en-cifras/

Stiles FG, Roselli L. Inventario de las aves de un bosque altoandino: Comparación de dos métodos. Caldasia. 1998;20(1):29-43.

Stiles FG, Bohórquez CI. Evaluando el estado de la biodiversidad: El caso de la avifauna de la serrania de las Quinchas, Boyacá, Colombia. Caldasia. 2000;22(1):61-92.

Stiles FG, Beckers J. Un inventario de las aves de la región de Inírida, Guainía, Colombia. Ornitol Colomb. 2016;15:21-52.

Stiles FG, Naranjo LG. La avifauna del parque nacional natural Chiribiquete: Resultados de tres expediciones recientes a sectores previamente inexplorados. Rev Colomb Amazon. 2017;(10):141-160.

Suarez AV, Tsutsui ND. The value of museum collections for research and society. BioScience. 2004;54:66-74. Doi: https://doi.org/10.1641/0006-3568(2004)054[0066:TVOMCF]2.0.CO;2

The World Bank. Data: Research and development expenditure (% of GDP) [24 November 2018]. 2018. Available in: http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS

UNESCO. How much does your country invest in R&D? [24 November 2018]. 2018. Available in: http://uis.unesco.org/apps/visualisations/research-and-development-spending/

Winston JE. Archives of a small planet: The significance of museum collections and museum based research in invertebrate taxonomy. Zootaxa. 2007;1668(1):47-54. Doi: http://dx.doi.org/10.11646/zootaxa.1668.1.6

Xeno-canto Foundation. Xeno-canto: Compartiendo cantos de aves de todo el mundo. [20 November 2018]. 2018. Available in: https://www.xeno-canto.org/

Yates TL. The role of voucher specimens in mammal collections: characterization and funding responsibilities. Acta Zool Fennica. 1985;(170):81-82.

APPENDIX

ON BIRDS OF SANTANDER-BIO EXPEDITIONS, QUANTIFYING THE COST OF COLLECTING VOUCHER SPECIMENS IN COLOMBIA

List of taxa recorded during the three expeditions of Santander Bio, Santander, Colombia, 2018.

The column "Taxon" refers to the taxonomy of the species according to Gill and Donsker (2018). "Support of the record" depicts the evidence for each taxa, considering voucher specimens and tissues as well as observational records (OR). For taxa with multiple support, we first present the material evidence, followed a ";" by the observational records. Species marked by asterisk (*) depict that they are recorded by first time by a voucher specimen for Santander. "Locality" refers to the localities indicated in Table 1, and also present first the localities for the material evidence followed after a ";" by localities with OR.

Taxon	Support of the record	Locality
Tinamiformes		
Tinamidae		
Red-legged Tinamou (*Crypturellus erythropus*) *	UIS-AV-2210, UIS-CT-344	2c
Anseriformes		
Anatidae		
Black-bellied Whistling Duck (*Dendrocygna autumnalis*)	OR	2b
Galliformes		
Cracidae		
Colombian Chachalaca (*Ortalis columbiana*) *	UIS-AV-2213, UIS-CT-352; OR	2f; 2b, 2e
Andean Guan (*Penelope montagnii*)	OR	3
Wattled Guan (*Aburria aburri*)	UIS-AV-2193, UIS-CT-213; OR	1g; 1a
Odontophoridae		
Gorgeted Wood Quail (*Odontophorus strophium*)	OR	1a
Ciconiiformes		
Ciconiidae		
Wood Stork (*Mycteria americana*)	OR	2b
Pelecaniformes		
Threskiornithidae		
Bare-faced Ibis (*Phimosus infuscatus*)	OR	2b, 2e
Ardeidae		
Rufescent Tiger Heron (*Tigrisoma lineatum*)	OR	2b
Cocoi Heron (*Ardea cocoi*)	OR	2e
Great Egret (*Ardea alba*)	OR	2b, 2e
Black-crowned Night Heron (*Nycticorax nycticorax*)	OR	2b
Western Cattle Egret (*Bubulcus ibis*)	OR	2b, 2e
Capped Heron (*Pilherodius pileatus*)	OR	2b

(*Continued*)

Taxon	Support of the record	Locality
Accipitriformes		
Cathartidae		
Turkey Vulture (*Cathartes aura*)	OR	2b, 2e, 3
Lesser Yellow-headed Vulture (*Cathartes burrovianus*)	OR	2b
Black Vulture (*Coragyps atratus*)	OR	1a, 1b, 1f, 2b, 2e, 3
King Vulture (*Sarcoramphus papa*)	OR	2b, 2e
Accipitridae		
Swallow-tailed Kite (*Elanoides forficatus*)	OR	1a, 2a
Black Hawk-Eagle (*Spizaetus tyrannus*)	OR	1f
Savanna Hawk (*Buteogallus meridionalis*)	OR	2a
Barred Hawk (*Morphnarchus princeps*)	OR	1a
Roadside Hawk (*Rupornis magnirostris*)	UIS-AV-2195, UIS-CT-316; OR	2a; 1b, 1d, 2b, 2e
Charadriiformes		
Charadriidae		
Southern Lapwing (*Vanellus chilensis*)	OR	1b, 1d, 2b
Jacanidae		
Wattled Jacana (*Jacana jacana*)	OR	2e
Columbiformes		
Columbidae		
Band-tailed Pigeon (*Patagioenas fasciata*)	OR	1f
Ruddy Pigeon (*Patagioenas subvinacea*)	OR	1f, 2b, 2e
Scaled Dove (*Columbina squammata*)	OR	2b
Plain-breasted Ground Dove (*Columbina minuta*)	OR	2b
Ruddy Ground Dove (*Columbina talpacoti*)	OR	1d, 2b, 3
White-tipped Dove (*Leptotila verreauxi*)	OR	1d, 2b, 2e
Cuculiformes		
Cuculidae		
Greater Ani (*Crotophaga major*)	OR	2b, 2e
Smooth-billed Ani (*Crotophaga ani*)	OR	1d, 2b, 2e, 3
Striped Cuckoo (*Tapera naevia*)	OR	1b, 1d, 2b
Little Cuckoo (*Coccycua minuta*)	OR	2e
Squirrel Cuckoo (*Piaya cayana*)	UIS-AV-2185, UIS-CT-186; OR	1d; 1b
Strigiformes		
Strigidae		
Cinnamon Screech Owl (*Megascops petersoni*) *	UIS-AV-2180, UIS-CT-174	1a

(*Continued*)

Taxon	Support of the record	Locality
Caprimulgiformes		
Nyctibiidae		
Common Potoo (*Nyctibius griseus*)	UIS-AV-2064, 2246, UIS-CT-325, 334	2b, 2e
Caprimulgidae		
Pauraque (*Nyctidromus albicollis*)	UIS-AV-2198, UIS-CT-324; OR	2d; 2b
Chuck-will's-widow (*Antrostomus carolinensis*)	UIS-AV-2155, UIS-CT-095	1a
Apodiformes		
Apodidae		
White-collared Swift (*Streptoprocne zonaris*)	OR	1d, 2b, 2e
Short-tailed Swift (*Chaetura brachyura*)	OR	2b, e
White-tipped Swift (*Aeronautes montivagus*)	OR	3
Trochilidae		
Green Hermit (*Phaethornis guy*)	UIS-AV-1937, 2260, UIS-CT-147, 202; OR	1a; 1b, 1f
Tawny-bellied Hermit (*Phaethornis syrmatophorus*)	UIS-AV-1925, UIS-CT-165, 183, IAvH-A (SBIO-89)	1a
Pale-bellied Hermit (*Phaethornis anthophilus*)	UIS-AV-2197, UIS-CT-322	2a
Green-fronted Lancebill (*Doryfera ludovicae*)	UIS-AV-1902, 2159, 2221, UIS-CT-103, 107, 160, 414, IAvH-A (SBIO-66)	1a, 3
Lazuline Sabrewing (*Campylopterus falcatus*)	UIS-AV-2113, 2140, UIS-CT-429, 454, 487, IAvH-A (SBIO-259)	3
Mexican Violetear (*Colibri thalassinus*)	UIS-AV-2095, 2080, 2114, UIS-CT-402, 404, 430, 486, 492, IAvH-A (SBIO-207, 291)	3
Black-throated Mango (*Anthracothorax nigricollis*)	OR	2e
Crowned Woodnymph (*Thalurania colombica*)	UIS-AV-1918, UIS-CT-146	1a
Rufous-tailed Hummingbird (*Amazilia tzacatl*)	OR	1b
White-vented Plumeleteer (*Chalybura buffonii*)	UIS-AV-2188, UIS-CT-199	1a
Speckled Hummingbird (*Adelomyia melanogenys*)	UIS-AV-2086, 2091, 2181, UIS-CT-175, 386, 394, 425, IAvH-A (SBIO-230)	1a, 3
Buff-tailed Coronet (*Boissonneaua flavescens*)	UIS-AV-2085, 2097, 2111, 2124, 2133, 2138, 2227, 2228, 2250, 2259, UIS-CT-358, 377, 384, 406, 426, 436, 438, 455, 469, 480, 481, 482. IAvH-A (SBIO-163, 285)	3
Mountain Velvetbreast (*Lafresnaya lafresnayi*)	UIS-AV-2236, UIS-CT-477	3
Black Inca (*Coeligena prunellei*)	UIS-AV-1901, 1917, 1926, 2182, 2183, 1929, 2186, UIS-CT-102, 109, 126, 145, 167, 177, 178, 181, 191, IAvH-A (SBIO-15, 32)	1a
Collared Inca (*Coeligena torquata*)	UIS-Av-2074, 2102, 2141, 2237, 2252, UIS-CT-357, 369, 382, 412, 479, 488, IAvH-A (SBIO-174)	3
Blue-throated Starfrontlet (*Coeligena helianthea*)	UIS-Av-2110, 2132, 2255, UIS-CT-403, 423, 468	3

(*Continued*)

Taxon	Support of the record	Locality
Trochilidae		
Longuemare's Sunangel (*Heliangelus clarisse*)	UIS-Av-2082, 2093, 2096, 2100, 2108, 2109, 2115, 2119, 2121, 2137, 2214, 2216, 2226, 2238, 2241, 2251, 2253, 2256, UIS-CT-356, 362, 367, 373, 379, 380, 395, 400, 405, 409, 410, 421, 422, 433, 434, 444, 448, 478, 483, 493, IAvH-A (SBIO-172, 178)	3
White-booted Racket-tail (*Ocreatus underwoodii*)	UIS-AV-2171, UIS-CT-149; OR	1a; 1f, 3
Tyrian Metaltail (*Metallura tyrianthina*)	UIS-AV-2073, 2101, 2122, 2136, 2231, UIS-CT-355, 411, 446, 447, 449, 473, 491, IA-vH-A (SBIO-252, 296)	3
Long-tailed Sylph (*Aglaiocercus kingie*)	OR	3
Geoffroy's Wedgebill (*Schistes geoffroyi*)	UIS-AV-2189, UIS-CT-200	1c
Trogoniformes		
Trogonidae		
Golden-headed Quetzal (*Pharomachrus auriceps*) *	UIS-AV-2243, UIS-CT-495; OR	3; 1e
Collared Trogon (*Trogon collaris*)	UIS-AV-2174, UIS-CT-157; OR	1a; 1f
Coraciiformes		
Alcedinidae		
American Pygmy Kingfisher (*Chloroceryle aenea*)	UIS-AV-2196, UIS-CT-318	2a
Amazon Kingfisher (*Chloroceryle amazona*)	OR	2a
Momotidae		
Whooping Motmot (*Momotus subrufescens*)	UIS-AV-2063, 2066, UIS-CT-321, 335	2a, 2d
Piciformes		
Bucconidae		
Moustached Puffbird (*Malacoptila mystacalis*)	UIS-AV-1915, 1931, 2184, UIS-CT-100, 141, 184, 185, IAvH-A (SBIO-6)	1a
Capitonidae		
White-mantled Barbet (*Capito hypoleucus*)	OR	1a
Ramphastidae		
Emerald Toucanet (*Aulacorhynchus prasinus*)	UIS-AV-2217, UIS-CT-366	3
Crimson-rumped Toucanet (*Aulacorhynchus haematopygus*)	UIS-AV-2179, UIS-CT-173; OR	1a; 1f
Collared Aracari (*Pteroglossus torquatus*)	OR	2b
Black-billed Mountain Toucan (*Andigena nigrirostris*)	UIS-AV-2125, 2126, UIS-CT-456, 457, 459, IAvH-A (SBIO-261)	3
Yellow-throated Toucan (*Ramphastos ambiguous*)	OR	2b
Picidae		
Olivaceous Piculet (*Picumnus olivaceus*)	OR	2
Acorn Woodpecker (*Melanerpes formicivorus*)	OR	3
Red-crowned Woodpecker (*Melanerpes rubricapillus*)	OR	2b, 2e

(*Continued*)

Taxon	Support of the record	Locality
Picidae		
Smoky-brown Woodpecker (*Leuconotopicus fumigatus*)	UIS-AV-2161, UIS-CT-120; OR	1a; 1f
Golden-olive Woodpecker (*Colaptes rubiginosus*)	OR	3
Spot-breasted Woodpecker (*Colaptes punctigula*)	OR	2b, 2e
Lineated Woodpecker (*Dryocopus lineatus*)	OR	2a
Powerful Woodpecker (*Campephilus pollens*)	UIS-AV-2240, UIS-CT-490; OR	3; 1a
Crimson-crested Woodpecker (*Campephilus melanoleucos*)	OR	2a
Falconiformes		
Falconidae		
Northern Crested Caracara (*Caracara cheriway*)	OR	2b, 2e
Yellow-headed Caracara (*Milvago chimachima*)	OR	2b, 2e
Laughing Falcon (*Herpetotheres cachinnans*)	OR	2e
American Kestrel (*Falco sparverius*)	OR	1b, 2e, 3
Bat Falcon (*Falco rufigularis*)	OR	1d
Psittaciformes		
Psittacidae		
Orange-chinned Parakeet (*Brotogeris jugularis*)	OR	2b
Saffron-headed Parrot (*Pyrilia pyrilia*) *	UIS-AV-1944, UIS-CT-151, 212, IAvH-A (SBIO-57)	1d, 1f
Blue-headed Parrot (*Pionus menstruus*)	OR	2b
Yellow-crowned Amazon (*Amazona ochrocephala*)	OR	2b, 2e
Spectacled Parrotlet (*Forpus conspicillatus*)	OR	2b
Brown-throated Parakeet (*Eupsittula pertinax*)	OR	2e
Blue-and-yellow Macaw (*Ara ararauna*)	OR	2b, 2e
Military Macaw (*Ara militaris*)	OR	2b
Chestnut-fronted Macaw (*Ara severus*)	OR	2b
Passeriformes		
Furnariidae		
Pale-legged Hornero (*Furnarius leucopus*) *	UIS-AV-2199, UIS-CT-326	2b
Pale-breasted Spinetail (*Synallaxis albescens*)	OR	1d
Rufous Spinetail (*Synallaxis unirufa*)	UIS-AV-2131, UIS-CT-462, 467, IAvH-A (SBIO-267)	3
Rusty-winged Barbtail (*Premnornis guttuliger*) *	UIS-AV-2089, 2230, UIS-CT-389, 441	3
Spotted Barbtail (*Premnoplex brunnescens*)	UIS-AV-1935, UIS-CT-170, 197, IAvH-A (SBIO-76)	1a
Pearled Treerunner (*Margarornis squamiger*)	UIS-AV-2092, 2094, UIS-CT-359, 399, 401, IAvH-A (SBIO-164)	3
Streaked Tuftedcheek (*Pseudocolaptes boissonneautii*)	UIS-AV-2116, UIS-CT-365, 435, IAvH-A (SBIO-170)	3

(*Continued*)

Taxon	Support of the record	Locality
Furnariidae		
Montane Foliage-gleaner (*Anabacerthia striaticollis*)	UIS-AV-1909, 2165 UIS-CT-114, 128, 134, IAvH-A (SBIO-20); OR	1a; 3
Lineated Foliage-gleaner (*Syndactyla subalaris*)	UIS-AV-1910, 2169, 2172, 2177, 1936, 1940, 1941, UIS-CT-131, 138, 150, 164, 168, 331, 205, 208, IAvH-A (SBIO-70)	1a
Plain Xenops (*Xenops minutus*)	UIS-AV-2206, UIS-CT-340	2c
Tyrannine Woodcreeper (*Dendrocincla tyrannina*) *	UIS-AV-2235, UIS-CT-476	3
Plain-brown Woodcreeper (*Dendrocincla fuliginosa*)	UIS-AV-2175, UIS-CT-162	1a
Olivaceous Woodcreeper (*Sittasomus griseicapillus*)	UIS-AV-2191, UIS-CT-207; OR	1a; 1f
Wedge-billed Woodcreeper (*Glyphorynchus spirurus*)	UIS-AV-2156, 2211, UIS-CT-098, 349	1a, 2c
Strong-billed Woodcreeper (*Xiphocolaptes promeropirhynchus*)	OR	3
Black-banded Woodcreeper (*Dendrocolaptes picumnus*)	UIS-AV-1906, 2176 UIS-CT-117, 166, 179, IAvH-A (SBIO-85); OR	1a; 1f
Straight-billed Woodcreeper (*Dendroplex picus*)	OR	2b
Streak-headed Woodcreeper (*Lepidocolaptes souleyetii*)	OR	2c
Brown-billed Scythebill (*Campylorhamphus pusillus*)	UIS-AV-1920, UIS-CT-152, 153, IAvH-A (SBIO-59)	1a
Thamnophilidae		
Slaty Antwren (*Myrmotherula schisticolor*)	UIS-AV-1903, 2170, 1938, 1939, 2192, 1942 UIS-CT-104, 144, 176, 190, 203, 204, 209, 210, IAvH-A (SBIO-82, 96)	1a
Bar-crested Antshrike (*Thamnophilus multistriatus*)	OR	1g
Uniform Antshrike (*Thamnophilus unicolor*)	UIS-AV-1943, UIS-CT-096, 211, IAvH-A (SBIO-2)	1a
	OR	1f
Bicolored Antbird (*Gymnopithys bicolor*) *	UIS-AV-2071, UIS-CT-348, 351, IAvH-A (SBIO-156)	2c, 2d
Parker's Antbird (*Cercomacroides parkeri*)	UIS-AV-2168, UIS-CT-137	1a
Chestnut-backed Antbird (*Poliocrania exsul*)	UIS-AV-2209, UIS-CT-343	2c
Formicariidae		
Unidentified Antthrush (*Chamaeza* sp.)	OR	1a
Grallaridae		
Chestnut-crowned Antpitta (*Grallaria ruficapilla*)	OR	1a, 3
Ochre-breasted Antpitta (*Grallaricula flavirostris*)	UIS-AV-2158, UIS-CT-110	1a
Conopophagidae		
Chestnut-crowned Gnateater (*Conopophaga castaneiceps*) *	UIS-AV-1900, 2187, UIS-CT-097, 156, 194, IAvH-A (SBIO-62)	1a
Tyrannidae		
Yellow-bellied Elaenia (*Elaenia flavogaster*)	OR	1b, 1d
Mouse-colored Tyrannulet (*Phaeomyias cf murina*)	UIS-AV-2207, UIS-CT-341	2c

(*Continued*)

Taxon	Support of the record	Locality
Tyrannidae		
Variegated Bristle Tyrant (*Pogonotriccus poecilotis*)	UIS-AV-1913, 2190, 2232, UIS-CT-139, 201, 458; OR	1a, 3; 1f
Olive-striped Flycatcher (*Mionectes olivaceus*)	UIS-AV-, 1921, 1923, 2098, 2117, 2157, 2261 UIS-CT-099, 118, 155, 159, 189, 407, 437 IAvH-A (SBIO-24)	1a, 3
Ochre-bellied Flycatcher (*Mionectes oleaginous*)	UIS-AV-2067, 2068, 2244, 2245, 2233, UIS-CT-317, 323, 338, 339, 474	2a, 2c, 3
Sepia-capped Flycatcher (*Leptopogon amaurocephalus*)	UIS-AV-2194, UIS-CT-105, 315, IAvH-A (SBIO-11)	1a, 2a
Flavescent Flycatcher (*Myiophobus flavicans*)	UIS-AV-2072, UIS-CT-354, 375, IAvH-A (SBIO-180)	3
Ornate Flycatcher (*Myiotriccus ornatus*)	UIS-AV-1916, 1933, UIS-CT-113, 119, 142, 193, IAvH-A (SBIO-19, 25)	1a
Black-throated Tody-Tyrant (*Hemitriccus granadensis*)	UIS-AV-2127, 2142 UIS-CT-378, 470, 489, IAvH-A (SBIO-183)	3
Southern Bentbill (*Oncostoma olivaceum*)	UIS-AV-2205, UIS-CT-337	2d
Common Tody-Flycatcher (*Todirostrum cinereum*)	OR	1b, 2b
White-throated Spadebill (*Platyrinchus mystaceus*)	UIS-AV-1904, UIS-CT-106, 143, IAvH-A (SBIO-49)	1a
Cinnamon Flycatcher (*Pyrrhomyias cinnamomeus*)	UIS-AV-2224, UIS-CT-431	3
Smoke-colored Pewee (*Contopus fumigatus*)	OR	3
Willow Flycatcher (*Empidonax traillii*)	UIS-AV-2178, UIS-CT-171	1a
Yellow-bellied Chat-Tyrant (*Silvicultrix diadema*)	UIS-AV-2077, 2120, UIS-CT-364, 396, 398, 445, IAvH-A (SBIO-201, 203)	3
Slaty-backed Chat-Tyrant (*Ochthoeca cinnamomeiventris*)	OR	3
Brown-backed Chat-Tyrant (*Ochthoeca fumicolor*)	OR	3
Cattle Tyrant (*Machetornis rixosa*)	OR	1b, 2e
Rusty-margined Flycatcher (*Myiozetetes cayanensis*)	OR	1b, 2e
Great Kiskadee (*Pitangus sulphuratus*)	OR	1b, 2e
Golden-crowned Flycatcher (*Myiodynastes chrysocephalus*)	UIS-AV-1907, UIS-CT-121, 123, IAvH-A (SBIO-29); OR	1a; 3
Streaked Flycatcher (*Myiodynastes maculatus*)	UIS-AV-2201, UIS-CT-328	2a
Tropical Kingbird (*Tyrannus melancholicus*)	OR	1b, 1d, 1f 2b, 2e, 3
Fork-tailed Flycatcher (*Tyrannus savanna*)	OR	1d, 2e
Apical Flycatcher (*Myiarchus apicalis*)	OR	3
Cotingidae		
Green-and-black Fruiteater (*Pipreola riefferii*)	UIS-AV-2104, 2105 UIS-CT-415, 416, 453, IAvH-A (SBIO-258)	3
Andean Cock-of-the-rock (*Rupicola peruvianus*) *	UIS-AV-2160, UIS-CT-115	1e
Dusky Piha (*Lipaugus fuscocinereus*) *	UIS-AV-2222, UIS-CT-418	3

(*Continued*)

Taxon	Support of the record	Locality
Pipridae		
Golden-winged Manakin (*Masius chrysopterus*)	UIS-AV-1912, 1924, 2166 UIS-CT-133, 135, 161, 163, 192, IAvH-A (SBIO-67, 98)	1a
White-bearded Manakin (*Manacus manacus*)	UIS-AV-2062, 2069, 2248, 2070 UIS-CT-319, 320, 345, 346, 347 IAvH-A (SBIO-125)	2a, 2c
Tityridae		
Masked Tityra (*Tityra semifasciata*)	OR	2b, 2e
Russet-winged Schiffornis (*Schiffornis stenorhyncha*)	UIS-AV-2208, UIS-CT-342	2c
Corvidae		
Black-chested Jay (*Cyanocorax affinis*)	UIS-AV-2202, UIS-CT-329; OR	2b; 2e
Inca Jay (*Cyanocorax yncas*)	UIS-AV-1932, UIS-CT-187, 188, IAvH-A (SBIO-93); OR	1a; 1f, 3
Hirundinidae		
White-winged Swallow (*Tachycineta albiventer*)	OR	2e
Southern Rough-winged Swallow (*Stelgidopteryx ruficollis*)	OR	1b, 2b
Barn Swallow (*Hirundo rustica*)	OR	2b
Donacobiidae		
Black-capped Donacobius (*Donacobius atricapilla*)	OR	1d
Troglodytidae		
Band-backed Wren (*Campylorhynchus zonatus*)	OR	1b, 1d
Bicolored Wren (*Campylorhynchus griseus*)	OR	1b, 2b, e
Rufous Wren (*Cinnycerthia unirufa*)	OR	3
House Wren (*Troglodytes aedon*)	UIS-AV-2081, 2103 UIS-CT-371, 376, 413, IAvH-A (SBIO-176); OR	3; 1b
White-breasted Wood Wren (*Henicorhina leucosticta*)	OR	1f, 3
Grey-breasted Wood Wren (*Henicorhina leucophrys*)	UIS-AV-1914, 1930, 2106, 2257 UIS-CT-140, 180, 182, 206, 417, 452, IAvH-A (SBIO-86, SBIO-112)	1a, 3
Mimidae		
Tropical Mockingbird (*Mimus gilvus*)	OR	1b, 1f, 2e, 3
Turdidae		
Swainson's Thrush (*Catharus ustulatus*)	OR	1a, b
Great Thrush (*Turdus fuscater*)	UIS-AV-2239, UIS-CT-485	3
Glossy-black Thrush (*Turdus serranus*)	UIS-AV-2220, UIS-CT-392	3
Pale-breasted Thrush (*Turdus leucomelas*)	OR	1b
Black-billed Thrush (*Turdus ignobilis*)	UIS-AV-2164, UIS-CT-130; OR	1a; 1d
Cinclidae		
White-capped Dipper (*Cinclus leucocephalus*)	OR	1e

(*Continued*)

Taxon	Support of the record	Locality
Fringillidae		
Yellow-bellied Siskin (*Spinus xanthogastrus*)	OR	1f
Thick-billed Euphonia (*Euphonia laniirostris*)	OR	1d, 2b
Golden-rumped Euphonia (*Euphonia cyanocephala*)	OR	1b
Passerellidae		
Rufous-collared Sparrow (*Zonotrichia capensis*)	OR	1a, 1b, 1d, 1f, 3
Chestnut-capped Brushfinch (*Arremon brunneinucha*)	UIS-AV-1911, 1928, 2084, 2088, 2173, 2254, UIS-CT-112, 132, 154, 172, 383, 388, 397, IAvH-A (SBIO-18)	1a, 3
Moustached Brushfinch (*Atlapetes albofrenatus*)	UIS-AV-2123, 2128, 2215, 2130, UIS-CT-361, 442, 450, 461, 465, IAvH-A (SBIO-247)	3
Slaty Brushfinch (*Atlapetes schistaceus*)	UIS-AV-2090, 2118 UIS-CT-390, 391, 439, IAvH-A (SBIO-196)	3
Icteridae		
Red-breasted Blackbird (*Leistes militaris*)	OR	2e
Crested Oropendola (*Psarocolius decumanus*)	OR	1a, 1b, 1d, 1f, 2b, 2e
Yellow-rumped Cacique (*Cacicus cela*)	OR	1d
Subtropical Cacique (*Cacicus uropygialis*) *	UIS-AV-1934, UIS-CT-195, 196, IAvH-A (SBIO-101); OR	1a; 1f
Northern Mountain Cacique (*Cacicus leucoramphus*)	UIS-AV-2107, UIS-CT-419, 420 IAvH-A (SBIO-224)	3
Yellow-backed Oriole (*Icterus chrysater*)	OR	3
Yellow Oriole (*Icterus nigrogularis*)	OR	2b
Orange-crowned Oriole (*Icterus auricapillus*)	OR	1b, 2e
Giant Cowbird (*Molothrus oryzivorus*)	OR	1b, 1d
Carib Grackle (*Quiscalus lugubris*)	UIS-AV-1919, UIS-CT-129, 148, IAvH-A (SBIO-35); OR	1a, 1d; 1b, 2b, 3
Yellow-hooded Blackbird (*Chrysomus icterocephalus*)	OR	2b
Parulidae		
Tropical Parula (*Setophaga pitiayumi*)	OR	1f
Blackburnian Warbler (*Setophaga fusca*)	UIS-AV-1905, UIS-CT-111, 124, IAvH-A (SBIO-30); OR	1a; 1b, 1f
Black-crested Warbler (*Myiothlypis nigrocristata*)	UIS-AV-2134, 2135, UIS-CT-466, 471, 472, IAvH-A (SBIO-271)	3
Russet-crowned Warbler (*Myiothlypis coronate*)	OR	3
Three-striped Warbler (*Basileuterus tristriatus*)	UIS-AV-2247, 1908, 1922, 1927, 2219, UIS-CT-101, 108, 116, 127, 158, 169, 374, IAvH-A (SBIO-7, 22); OR	1a, 1d, 3; 1f
Canada Warbler (*Cardellina canadensis*)	UIS-AV-2163, UIS-CT-125	1a
Slate-throated Whitestart (*Myioborus miniatus*)	UIS-AV-2167, UIS-CT-136; OR	1a; 1f
Golden-fronted Whitestart (*Myioborus ornatus*)	UIS-AV-2075, UIS-CT-360, 451, IAvH-A (SBIO-256)	3

(*Continued*)

Taxon	Support of the record	Locality
Cardinalidae		
Summer Tanager (*Piranga rubra*)	OR	1b
Sooty Ant Tanager (*Habia gutturalis*)	UIS-AV-2212, UIS-CT-350	2c
Thraupidae		
White-capped Tanager (*Sericossypha albocristata*)	OR	3
Black-capped Hemispingus (*Hemispingus atropileus*)	UIS-AV-2223, UIS-CT-427	3
Superciliaried Hemispingus (*Hemispingus superciliaris*) *	UIS-AV-2229, UIS-CT-440	3
Black-eared Hemispingus (*Hemispingus melanotis*)	UIS-AV-2083, 2112, UIS-CT-381, 424, 428, IAvH-A (SBIO-229)	3
Crimson-backed Tanager (*Ramphocelus dimidiatus*)	UIS-AV-2203, UIS-CT-330; OR	2b; 1b, 1f
Lemon-rumped Tanager (*Ramphocelus icteronotus*)	OR	1b, 1d
Blue-grey Tanager (*Thraupis episcopus*)	OR	1a, 1b, 1d, 1f, 2e, 3
Palm Tanager (*Thraupis palmarum*)	OR	1b, 1f, 2e
Blue-capped Tanager (*Thraupis cyanocephala*)	UIS-AV-2129, UIS-CT-463, 464 IAvH-A (SBIO-269)	3
Buff-breasted Mountain Tanager (*Dubusia taeniata*)	UIS-AV-2225, UIS-CT-432	3
Golden Tanager (*Tangara arthus*)	OR	1f
Flame-faced Tanager (*Tangara parzudakii*) *	UIS-AV-2162, UIS-CT-122	1a
Scrub Tanager (*Tangara vitriolina*)	OR	1a, 1b
Blue-necked Tanager (*Tangara cyanicollis*)	OR	1d, 1f
Black-capped Tanager (*Tangara heinei*)	OR	1c
Capped Conebill (*Conirostrum albifrons*)	UIS-AV-2218, UIS-CT-372	3
White-sided Flowerpiercer (*Diglossa albilatera*)	UIS-AV-2076, 2079, 2087, 2099, 2258 UIS-CT-353, 363, 370, 387, 393, 408, 443, 460, IAvH-A (SBIO-158, 198, 248)	3
Masked Flowerpiercer (*Diglossa cyanea*)	UIS-AV-2078, UIS-CT-368; (SBIO-190), UIS-CT-385; UIS-AV-2139, UIS-CT-484	3
Slaty Finch (*Haplospiza rustica*) *	UIS-AV-2234, UIS-CT-475	3
Saffron Finch (*Sicalis flaveola*)	UIS-AV-2065, UIS-CT-332, 333, IAvH-A (SBIO-137); OR	2b; 1b, 1d, 2e
Black-winged Saltator (*Saltator atripennis*)	OR	1c
Blue-black Grassquit (*Volatinia jacarina*)	OR	1b
Slate-colored Seedeater (*Sporophila schistacea*)	UIS-AV-2204, UIS-CT-331	2b
Grey Seedeater (*Sporophila intermedia*)	UIS-AV-2200, UIS-CT-327; OR	2b; 1f
Yellow-bellied Seedeater (*Sporophila nigricollis*)	OR	1b, 1f, 2a, 3
Ruddy-breasted Seedeater (*Sporophila minuta*)	OR	2b, 2e
Bananaquit (*Coereba flaveola*)	OR	1b, 2b
Yellow-faced Grassquit (*Tiaris olivaceus*)	OR	3
Plushcap (*Catamblyrhynchus diadema*)	UIS-AV-2242, UIS-CT-494	3