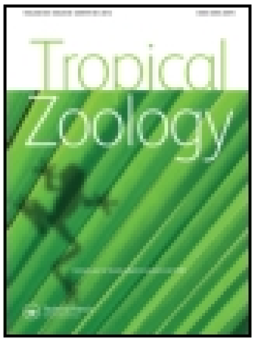

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Synopsis and potential geographical distribution of *Cotinis* (Coleoptera: Scarabaeidae: Cetoniinae: Gymnetini) in Colombia

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A taxonomic synopsis and analysis of the potential distribution of the three *Cotinis* species found in Colombia are presented, based on the revision of 212 specimens deposited in 20 entomological collections. Based on collection information and geo-referencing locality data, the rate of record accumulation over time and observed distribution for each species were examined. Potential distribution maps were generated following biogeographic, bioclimatic, conservation, and expert criteria. Potential distribution models were made according to the amount and degree of record spatial aggregation. Cundinamarca, Tolima, Magdalena, and Sucre are the departments with the greatest number of species occurrence data. The analysis of potential distribution showed that *Cotinis columbica* is restricted to Andean ecosystems, while *Cotinis lebasi* is showing potential distribution in humid tropical forest areas in Colombia. On the other hand, the Jackknife test indicated that available data for *Cotinis barthelemyi* do not provide a potential distribution model better than would be expected from chance. With the increase in comprehensive taxonomic monographs, which compile high quality collection data, this type of analysis could be implemented for other groups of Scarabaeoidea in Colombia to evaluate the temporary and spatial representativeness of sampling across different scales.

Keywords: Biodiversity; fruit scarab beetles; National System of Protected Areas; potential survey areas; taxonomy

Introduction

The New World genus *Cotinis* Burmeister, 1842 currently includes 28 species (Woodruff 2008; Gasca-Álvarez and Deloya 2015), which are distributed from the central and southern United States to northern South America (Deloya and Ratcliffe 1988; Woodruff 2008). According to the shape of the frontal projection and its degree of fusion to the head, three subgenera are recognized currently: *Cotinis* Burmeister, 1842 (25 species), *Criniflava* Goodrich, 1966 (two species), and *Liberocera* Deloya & Ratcliffe, 1988 (one species).

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Mexico has the largest number of species (18), of which 14 are considered endemic; these are associated with various habitats including deserts, grasslands, thorn scrub, tropical rain forests, deciduous forests, and temperate cloud forests (Deloya and Ratcliffe 1988; Deloya et al. 2000). In the United States, five species are known: *Cotinis aliena* Woodruff, 2008, *Cotinis boylei* Goodrich, 1966, *Cotinis impia* (Fall, 1905), *Cotinis mutabilis* (Gory & Percheron, 1833), and *Cotinis nitida* (Linnaeus, 1764) (Goodrich 1966; Woodruff 2008); these are distributed throughout the southern region of the country, except for *Cotinis aliena*, which is endemic to the Florida Keys. In Costa Rica, four species are reported: *Cotinis lebasi* (Gory & Percheron, 1833), *C. mutabilis*, *Cotinis olivia* Bates, 1889, and *Cotinis polita* Janson, 1876 (Solis 2004), which are mostly associated with lowlands on the Atlantic slope. Three species are recorded in Guatemala: *Cotinis fuscopicea* Goodrich, 1966, *C. mutabilis*, and *Cotinis viridicyanea* (Perbosc, 1839) (Orozco 2012a). The South American species occur in Colombia and Venezuela. Three species are in Colombia: *Cotinis barthelemyi* (Gory & Percheron, 1833), *Cotinis columbica* Burmeister, 1842, and *C. lebasi*. *Cotinis barthelemyi* and *Cotinis columbica* are endemic to the country with Andean and Caribbean distributions. Venezuela has a single species, *Cotinis patricialvarezae* Gasca-Álvarez & Deloya, 2015, recently described from the foothills of the Cordillera de Mérida (Gasca-Álvarez and Deloya 2015).

Cotinis (*sensu lato*) is recognized by the head in both sexes bearing more or less distinct frontal and clypeal processes, which are variable in form from species to species; antennal scape moderate in size, not as long as the combined length of the next four antennomeres combined; pronotum trapezoidal, smooth to strongly punctate, median portion of anterior margin in some specimens produced into a noticeable hump; elytra smooth to punctate-striate, with or without distinct longitudinal costae; mesometasternal process flattened ventrally, usually rounded at apex; protibia usually tridentate in females and bidentate in males; distal portion of meso- and metatibia with a pair of apical spines, protibia with a single apical spine; pygidium usually transversely strigulate and glossy; coloration variable from black, black with orange, reddish orange to green or green with orange (Goodrich 1966; Deloya and Ratcliffe 1988).

Scarab beetles of the subfamily Cetoniinae have been little studied in Colombia. Studies on taxonomy and ecology are still scarce. Suárez-and Amat-García (2007) and Neita et al. (2010) provided species lists for the country, including distributional data for *Cotinis*. Orozco and Pardo-Locarno (2004) described the larvae and pupae of three species and provided new distributional records. Regional studies, such as Útima and Vallejo (2008) for Risaralda, Neita et al. (2006) and Neita (2011) for Chocó, Pardo-Locarno (2013) for Valle del Cauca, and García-Atencia and Martínez-Hernández (2015) for Atlántico, have increased knowledge about the distribution and natural history of some cetoniine species in Colombia. Other occurrence data for the country can be found in several taxonomic revisions (Ratcliffe 1978; Orozco 2012b; Ratcliffe 2013a, 2013b; Ratcliffe 2015; Shaughney and Ratcliffe 2015). Given this background, available information for *Cotinis* in Colombia is dispersed, with a local scope and lack of clarity about their distribution in the country. This is not only true for *Cotinis* but also for most of the species of Cetoniinae in Colombia (Orozco and Pardo-Locarno 2004).

Species distribution models (SDMs) use geographic information to estimate the environmental requirements that predict a species' potential distribution (Peterson et al. 2011). Some of these algorithms use localities from museum specimens or observations to estimate a suitability area where the species may be found. SDMs can be used for species with a limited number of known localities or gaps in their geographic distribution (Raxworthy et al. 2003). In recent years, SDMs have been widely used in biogeography, ecology, and conservation (e.g. Chefaoui et al. 2005; Gutiérrez-Velázquez et al. 2013).

As a contribution to the knowledge of the cetoniine fauna of Colombia, this work presents an updated taxonomic synopsis of the *Cotinis* species that occur in Colombia and examines their potential distributions based on geographical, bioclimatic, and conservation criteria obtained with SDMs.

Material and methods

Taxonomic treatment

The identification of species was made with descriptions and keys by Goodrich (1966), Solís (2004), and Gasca-Álvarez and Deloya (2015). For each species, we provide the following information: Diagnosis, geographic distribution, potential distribution model, specimens examined, and taxonomic and biological remarks.

For the study of male genitalia, it was necessary to examine the form of the parameres because, with some exceptions, they are diagnostic. The specimen was immersed in hot water mixed with liquid soap for several minutes in order to soften the body. The parameres were removed through the anal opening.

A dichotomous key is presented for Colombian species. We used characters that are consistently expressed, with low intrinsic variability and observed with reasonable procedures. Photographs were taken using an AutoMontage system by Syncroscopy located at the Florida State Collections of Arthropods (Gainesville, Florida, USA), and a Canon 7d with 60 mm macro lens.

Taxonomic records

Specimens with records from Colombia were examined from 20 institutional collections: American Museum of Natural History, New York, USA (AMNH); Colección Entomológica del Programa de Biología de la Universidad de Caldas, Manizales, Colombia (CEBUC); Colección Entomológica Universidad de Nariño, Pasto, Colombia (CEUN); Colección Taxonómica Nacional de Insectos "Luís María Murillo" – CORPOICA, Mosquera, Colombia (CTI), Colección de Entomología Universidad de los Andes, Bogotá, Colombia (E-ANDES); Eastern Illinois University Insect Collection, Charleston, IL, USA (EIUIC); Field Museum, Chicago, IL, USA (FMNH); Florida State Collection of Arthropods, Gainesville, FL, USA (FSCA); Instituto Alexander von Humboldt, Villa de Leyva, Colombia (IAvH); Instituto de Ciencias Naturales Universidad Nacional de Colombia, Bogotá, Colombia (ICN); Instituto de Ecología A. C., Xalapa, Veracruz, México (IEXA); Laboratorio de Entomología de la Universidad de Caldas, Manizales, Colombia (LEBUC); Museo Entomológico Francisco Luís Gallego Universidad Nacional de Colombia, Medellín, Colombia (MEFLG); Museo de Historia Natural, Universidad de Caldas, Manizales, Colombia (MHN-UCa); Museo Entomológico Insectario Piedras Blancas, Medellín, Colombia (MEPB); Museo Javeriano de Historia Natural Pontificia Universidad Javeriana, Bogotá, Colombia (MUJ); Museo de Entomología Universidad Del Valle, Cali, Colombia (MUSENUV); Natural History Museum of Los Angeles County, Los Angeles, CA, USA (NHMLACM); Museo Entomológico de la Facultad de Agronomía Universidad

Nacional de Colombia, Bogotá, Colombia (UNAB); Museo de Historia Natural "Francisco Luís Gonzalo Andrade", Universidad Pedagógica y Tecnológica de Colombia, Tunja, Colombia (UPTC).

Additional records for *C. lebasi* from other countries were obtained from the following collections: The Natural History Museum, London, United Kingdom (BMNH), Canadian Museum of Nature, Ottawa, Canada (CMNC), Edward G. Riley Collection, College Station, TX, USA (EGRC), Instituto Nacional de Biodiversidad, San José, Costa Rica (INBIO) (housed in Museo Nacional de Costa Rica, San José, Costa Rica - MNCR), Smithsonian Tropical Research Institute Insect Collection, Panamá (STRI), Texas A&M University Insect Collection, College Station, TX, USA (TAMUIC), Colección de Artrópodos Universidad del Valle de Guatemala, Ciudad de Guatemala, Guatemala (UVGC).

To assess the known distribution of *Cotinis* species in Colombia, we built a dataset table with the following fields: collection code, specimen code, taxonomic determination, sex, country, department (state), municipality, specific locality of collection, date of collection (where available), geographical coordinates (in decimal format), altitude in meters (where available), and collector. If the geographical coordinates were not available, we assigned them by searching in Google Maps (www.coordenadas-gps.com).

Distribution modeling

We used occurrence data and 21 climatic and topographic variables, with 2.5 arc-min resolution (ca. 5×5 km), to estimate the potential distribution for the Colombian *Cotinis* species: 19 bioclimatic variables available in Worldclim 1.4 (Hijmans et al. 2005) and two topographic variables, elevation and slope (https://www2.jpl.nasa.gov/srtm/). We used Worldclim nomenclature to call the bioclimatic variables (Bio 1–Bio 19; Table S1).

The geographic extent or accessibility area ("M") to build the potential distribution models, must include occurrence records that represent the environmental spectrum where the species could be present (Soberón and Peterson 2005; Barve et al. 2011). However, it is necessary to assume that we do not have all the records of the occurrence of the *Cotinis* species of Colombia, and we accept that our knowledge about the habitat preferences of the Neotropical *Cotinis* species is still incipient. Therefore, we delimit the geographical extension of modeling based on biotic regions (Barve et al. 2011). Thus, the M area for each species was made up of the biographic provinces with at least one record of the species. For this, we use the most recent classification of Neotropical biogeographic provinces (e.g. Morrone 2014).

We obtained potential distribution models from MAXENT version 3.3.3 k (Phillips et al. 2006). Since species differ in the number and spatial distribution of records, the modeling protocol was adjusted according to each case. For *C. barthelemyi*, few presence records are available (<9), therefore, modeling was validated using the Jackknife method, which is optimal for evaluating models built with few records (Pearson et al. 2007). P values greater than 0.05 indicate that the model cannot predict the potential distribution better than chance. For *C. lebasi* and *C. columbica*, the occurrence data are spatially aggregated; in this case, we applied a 20-km spatial filter to the records that were included in the analyses (see Kramer-Schadt et al. 2013).

For *C. lebasi* and *C. columbica*, we calibrated the models using 75% of records, leaving the rest to validate the model. The models were validated with the ROC Partial Test (Peterson et al. 2008) using the software Partial-ROC version 1.0 (Barve 2008). This test solves the problem of assigning the same weight to commission and omission errors from the Area under the Curve test (AUC) (Lobo et al. 2008).

In all cases, we obtained potential distribution maps from the logistic output. We used the environmental variables contribution to explain the presence of each species, which we evaluated with response curves and Jackknife tests from Maxent. We examined the potential distribution models with binary maps defined by "10th percentile training presence" threshold and adjusted according to expert opinion (HJGA and CD).

For each species, we calculated the percentage of the potential distribution area that falls within the National System of Protected areas to identify priority or critical areas for collecting and conservation of *Cotinis* in Colombia. Finally, we evaluated the overlap among potential distributions to analyze the spatial degree of co-occurrence in Colombia. Localities, binary maps, and potential distribution maps were processed using ArcGis 10.2.2 (ESRI Inc 1999–2014).

Results

Taxonomy

Cotinis barthelemyi (Gory & Percheron, 1833)
(Figures 1A–F and 2)

Gymnetis barthelemy Gory and Percheron 1833: 333 (original combination)

Diagnosis

Length 27.5–30.2 mm; width 14.3–16.9 mm. Dorsal surface opaque green, violaceous laterally (Figure 1A). Ventral surface bright green. Clypeal projection variable, parallel or expanded apically. Frontal projection well developed, free at apex, fused 70% to the head, parallel or slightly expanded apically (Figure 1B,C). Elytra with two longitudinal costae converging at apical umbone. Males and females with tridentate protibiae. Mesometasternal projection broad, pentagonal with rounded apex (Figure 1D). Surface of pygidium with transverse strigulations (Figure 1E). Parameres robust, quadrangular, narrowed in the middle third, apex truncate to rounded, anterolateral projections developed, former into lobes directed at right angle (Figure 1F). Internal sac with a single, stout spine.

Distribution

This species is known only from Colombia, with records in Atlántico, Bolívar, Caldas, Magdalena, Santander, and Tolima (Figure 2).

Specimens examined

14 specimens, 9 ♂, 5 ♀. **Atlántico:** Barranquilla, 15-x-1970, G. Zambrano col., 1 ♀ [39468 - ICN]; 8-iii-1994, 11°00′ N, 74°48′ W, 68 m a.s.l., G. González col., 1 ♂, 1 ♀ [3010, 208 – UNAB]; Repelón, Bijibana, 10°30′05″, 75°80′01″W, 170 m a.s.l., H.

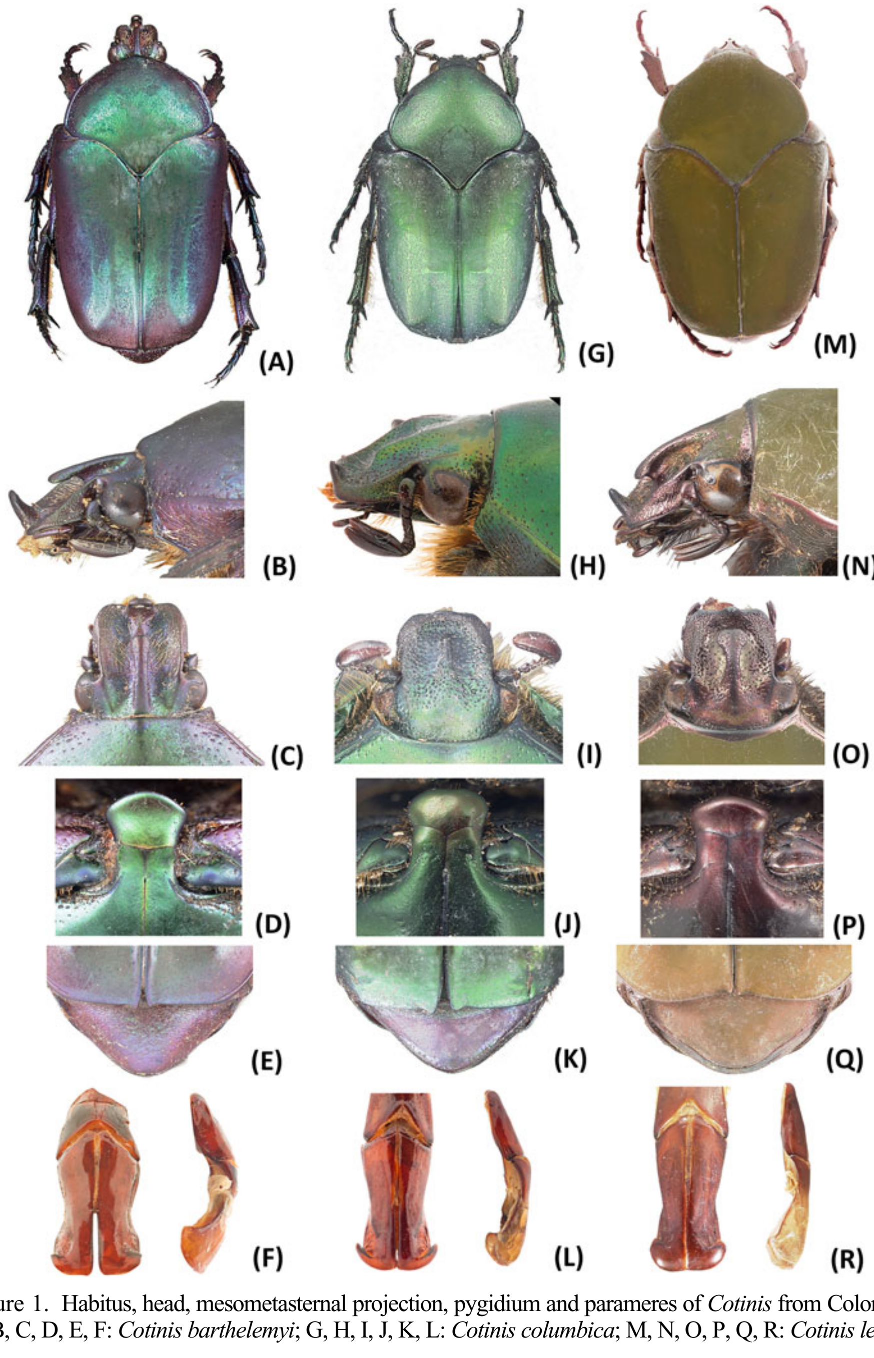

Figure 1. Habitus, head, mesometasternal projection, pygidium and parameres of *Cotinis* from Colombia. A, B, C, D, E, F: *Cotinis barthelemyi*; G, H, I, J, K, L: *Cotinis columbica*; M, N, O, P, Q, R: *Cotinis lebasi*.

Beltrán col., 1 ♀ [ICN]. **Bolivar:** SFF Los Colorados, no data, 9°51′33″N, 73°06′38″W, 300 m a.s.l., F. Escobar col., 1 ♂; Zambrano, Hacienda Monterrey, viii-1996, 9°37′40″N, 74°59′44″W, 120 m a.s.l., F. Escobar col., 1 ♂ [IAVH]. **Caldas**: La Dorada, Guarinocito, 17-iv-1989, 480 m a.s.l., Arango Orozco, Higuera Saguino Arce cols, 1 ♂ [39467 - ICN]. **Magdalena:** Santa Marta, Cerros de la ciudad, 01-vii-2004, 200 m a.s.l., W. Mendieta, L. Jimenez cols, 2 ♀ [39469 – ICN, EIUIC]; Cerro

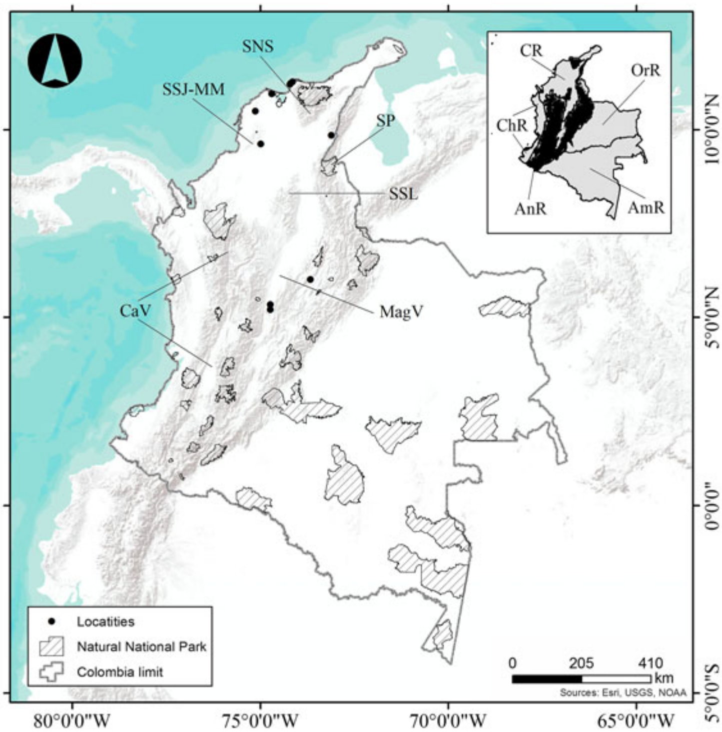

Figure 2. Locality records of *Cotinis barthelemyi*. SNS = Sierra Nevada de Santa Marta; SSJ - MM = Serrania de San Jacinto - Montes de María; SP = Serrania del Perijá; SSL = Serranía de San Lucas; MagV = Inter-Andean valley of Magdalena river and CaV = Inter-Andean valley of Cauca river. Inner map: CR = Caribean region; OrR = Orinoquía region; ChR = Choco region; AmR = Amazonas region and AnR = Andean region (black area show the Andean range from 500 m).

La Llorona, 11-x-2005, C. Valverde col., 1 ♂ [39504 – ICN]; PNN Tayrona Gairaca Abanico fluvial, 5-x-1976, 11-xi-1977, C. Kugler col., 2 ♂ [IAvH, UPTC]. **Santander:** Santander, Velez, iii-1976, L. Angel col., 1 ♂ [39470 – ICN]. **Tolima:** Honda, no data, 1 ♂ [EIUIC].

Remarks

Gory and Percheron (1833) originally described this species as *Gymnetis barthelemy*. Burmeister (1842) emended this name to *Cotinis bartholomaei*. Bates (1889) used a correct emendation according to present day usage to *C. barthelemyi*. Goodrich (1966) suggested that the modern ending for a patronym used by Bates (1889) must be adopted.

Adults have been found in dry, sub-xerophytic forests, collected with fruit traps inside the forest (García-Atencia and Martínez-Hernández 2015). Feeding habits are unknown. Specimens have been captured mostly from near sea level to 1200 m elevation, rarely above 1800 m elevation.

Cotinis barthelemyi is similar to *C. patricialvarezae* from Venezuela in coloration and shape of the clypeal and frontal projections. These species can be distinguished by size, shape of the mesometasternal projection, and parameres (Gasca-Álvarez and Deloya 2015).

Cotinis columbica Burmeister, 1842
(Figures 1G–L and 3)

Cotinis columbica Burmeister 1842: 258 (original combination)

Diagnosis

Length 17.6–29.1 mm; width 12.6–16.4 mm. Dorsal surface bright green, sometimes slightly opaque, rarely with red-brown reflections (Figure 1G). Ventral surface bright green. Clypeal projection short, triangular. Frontal projection fused to the head (Figure 1H, I). Elytra with two longitudinal costae slightly marked. Males and females with tridentate protibiae. Mesometasternal projection short, broad, apex rounded (Figure 1J). Pygidial disc smooth, with some rounded punctures at apex (Figure 1K). Parameres elongate, sides slightly curved, anterolateral projections forming lobes directed backward (Figure 1L). Internal sac with two thin, short spines.

Distribution

This species is known only from Colombia, with records from Caldas, Cauca, Cundinamarca, Huila, Meta, Risaralda, Tolima, and Valle del Cauca.

Potential distribution model

The model of *C. columbica* (Figure 3) shows values for the AUC test =0.95 and ROC Partial test =1.83 ± 0.07 ($p < 0.001$). This model suggests an Andean pattern with continuous distribution in the Central, Eastern and Western Cordilleras of Colombia, reaching Serrania de San Lucas, with a disconnected area in Serrania de San Jacinto (Montes de Maria) in Bolivar Department.

Specimens examined

127 specimens (23 ♂, 104 ♀). **Caldas:** Anserma, Finca La Palmeira, 20-iv-2014, 1800 m a.s.l., L. Campeon, C. Colorado cols, 1 ♀ [LEBUC]; La Dorada, Base de la FAC, 13-vii-1986, 190 m a.s.l., O. Ricardo col., 1 ♀ [MUJ], 30-i-2008, Bedoya Merchán col., 1 ♀ [LEBUC], 21-v-1977, 5°27′24″N, 74°40′02″W, 178 m a.s.l., L.G. Zapata col., 1 ♀ [213 – UNAB]; Norcasia, Rio Manso, 20-vi-2014, 700 m a.s.l., K. Norena col., colecta manual, 1 ♀ [CEBUC]; Palestina, 5-xi-1995, 1630 m a.s.l., Sierra col., al vuelo, 1 ♀ [LEBUC]; Pensilvania, El Boque, 2-v-2012, 2150 m a.s.l., O. J. Ramirez col., material de litera, 1 ♀ [LEBUC]. **Cauca:** Santander de Quilichao, Mondomo, 5-i-1976, 150 m a.s.l., 1 ♀ [MUSENUV]. **Cundinamarca:** Agua de Dios, Los Chorros, 12-x-1997, 4°22′41″N, 74°40′26″W, 400 m a.s.l., J.C. Martínez, D. Vanegas cols, 1 ♂ [UNAB]; Anolaima, 16-i-1982, M. Rojas, J. Rojas cols, 1 ♀ [56076 – ICN]; Arbeláez, 26-Nov-13, 14°16′N, 74°24′W, 1417 m a.s.l., J. Díaz col., 1 ♀ [UNAB]; Bogotá, 11-i-1975, R. Caceres col., 1 ♀ [208 – UNAB]; no data, 1 ♂, 2 ♀ [AMNH, EIUIC]; Fusagasugá, 2-x-1972, M. A. Mazorka col., 2 ♀ [39458, 39459 – ICN], iv-2001, D. Matute col., 1 ♂ [E-ANDES]; Guaduas, 16-vii-1972, C. I. Orozco col., 27-iv-1968, F. Nuñez col., iv-1968, Restrepo Mej col., 1 ♂, 2 ♀ [39457, 39463, 39139 – ICN]; Guayabetal, vi-1930, L. E. Aguirre col., 1 ♂ [39466 – ICN]; La Mesa, Calcuta, 18-x-1997, E. Barón col.;

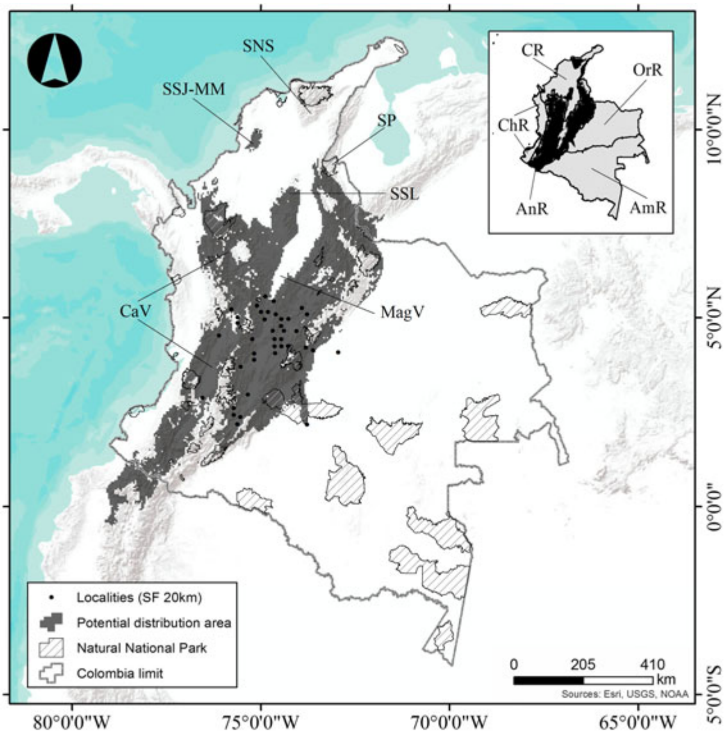

Figure 3. Potential distribution of *Cotinis columbica* according to threshold "10th percentile training presence." SF 20km = Spatial filter at 20 km. SNS = Sierra Nevada de Santa Marta; SSJ - MM = Serrania de San Jacinto - Montes de María; SP = Serrania del Perijá; SSL = Serranía de San Lucas; MagV = Inter-Andean valley of Magdalena river and CaV = Inter-Andean valley of Cauca river. Inner map: CR = Caribean region; OrR = Orinoquía region; ChR = Choco region; AmR = Amazonas region and AnR = Andean region (black area show the Andean range from 500 m).

Laguna de Pedro Palo, 11-ix-2003, J. Pardo col.; Urbanización La Carolina, 11-ix-2003, L. Pérez col.; Zona Urbana, 11-ix-2003, 12-ix-2003, A. Forero col.; Vda. San Javier, 11-x-2003, D. Melo col.; 5-iv-1994, B. Bello col., 7-v-1997, M. Peña col.; 24-iv-2002, R. Peña col.; 8-iv-2004, L. Imbachi col., 13 ♂, 17 ♀ [UNAB]; La Vega, Tabacal, 05-x-2003, 4°59′57″N, 74°20′23″W, 1230 m a.s.l., A. Díaz col.; 17-Ago-1997, D. Rodríguez col., 2 ♀ [208, 3010 – UNAB]; Nilo, 20-ix-1995, 4°18′36″N, 74°37′25″W, 336 m a.s.l., J. Torres col., 1 ♂ [UNAB]; Pandi, 21-vi-1940, 1024 m a.s.l., L. M. Murillo col., 1 ♀ [CTI]; Sasaima, 7-iv-1974, O. Rangel col., 1 ♂ [39465 – ICN]; Tena, 30-vi-1972, 1 ♀ [39143 – ICN], 07-ii-1981, 4°39′33″N, 74°23′28″W, 1384 m a.s.l., Vargas col., 1 ♂ [UNAB]; Tocaima, 18-x-1974, 4°27′40″N, 74°35′10″W, 400 m a.s.l., A. Fauta col., 1 ♂ [UNAB]; Villeta, 9-iv-1946, F. J. Ortega col., 1 ♀ [CTI], 18-ii-1977, 5°00′52″N, 74°28′33″W, 804 m a.s.l., E. Quiroga col., 1 ♀ [UNAB], iv-2008, S. Niño col., 1 ♀ [ICN]; Viotá, 19-iii-1958, A. Duarte col., 1 ♂ [CTI]. **Huila:** Garzón, vii-1944, Gallego col., 1 ♀ [MEFLG], 12-v-1974, H. Ramírez col., 2 ♀ [39142, 39464 – ICN]; 3-iii-2012, 828 m a.s.l., Perdomo Vargas col., 27-iii-2012, 830 m a.s.l., Cabrera col., 2 ♀ [LEBUC]; Gigante, xi-1969, 2 ♀ [FSCA], x-1978, 1 ♂ [LACM]; Neiva, xii-1974, B. & B. Mc Kay cols, no data - 2006, 2 ♀ [39140, 56072 - ICN]; Palermo, El Morral, 20-iii-2010, Y. Cifuentes & L. González cols, 1 ♀ [LEBUC]; Tesalia,Vda. El Espinal, Finca Los Cauchos, 18-x-2011, 830 m a.s.l., 2°27′49.89″N, 75°39′50.54″W, J. Forero col., 1 ♀ [UNAB]. **Meta:** La Macarena, 26-iii-1997, 580 m a.s.l., 2°11′17″N, 73°47′55″W, E.

Bastida col., 1 ♀ [UNAB]; Puerto López, Vereda Menegue, 14-iv-1984, 290 m a.s.l., Lamprea. L. col., 1 ♀ [39144 – ICN]; Villavicencio, 17-viii-1976, P. Dávila, 05-v-1974, E. Muñoz, 467 m a.s.l., 4°09′N, 73°39′W, 2 ♀ [UNAB], 9-iv-1968, C. Gómez col., 1 ♂ [39461 – ICN]. **Risaralda**: Santa Rosa de Cabal, Unisarc, 02-x-2012, 1580 m a.s.l., 4°55′N, 75°37′W, V. Gutiérrez col., 1 ♀ [UNAB]. **Tolima:** Armero, 12-i-1948, J. J. Castaño col., 1 ♀ [MEFLG], Carmen de Apicalá, Parque central, 20-iv-14, 371 m a.s.l., 4°7′N, 74°44′W, J. Quevedo col., 1 ♀ [UNAB], Chaparral, 15-ix-1972, 11-vi-1973,11-iii-1973, L. Quiñonez col., 3 ♀ [39462, 39141, 39460 – ICN]; Colegio, 16-Oct-1998, 339 m a.s.l., 4°27′26"N, 74°54′04"W, L. Ortiz col., 1 ♀ [UNAB]; Fálan, 18-viii-2003, 983 m a.s.l., 5°07′36"N, 74°57′18"W, H. Ávila col., 1 ♀ [UNAB]; Ibagué, 14-iv-1995, M. López col., 26-ix -1988, A. Rubio col., 1265 m a.s.l., 4°26′50″N, 75°14′44″W, 1 ♂, 1 ♀ [UNAB]; no data, 1 ♀ [FMN]; Mariquita, iii-1943, Gallecol col., 1 ♀ [MEFLG], 23-xii-2010, L. Pollo col., 1 ♀ [LEBUC], 7-viii-2006, 15-viii-2001, 5-viii-2000, Salazar col., 3 ♀ [MNH_Uca]; 27-iii-1994, 328 m a.s.l., 5°12′10"N, 74°55′49"W, J. Ortíz col., 1 ♀ [UNAB]; Manrique, 05-i-1997, 328 m a.s.l., 5°12′10"N, 74°55′49"W, O. Becerra col., 1 ♀ [UNAB]; Melgar, Via Melgar-Bogotá, Finca Piamonte (Salero), 29-iv-2009, W. Rodríguez col., 26-iv-2009, O. Alonso col., 1 ♂, 4 ♀ [UNAB]; 10-v-1995, 23-ii-10, 323 m a.s.l., 4°12′24″N, 74°38′44″W, F. Pereira col., 22-Oct-11, 342 m a.s.l., J. Sanita col.; Vda. Buenavista, Finca Villa del Carmelo, 23-ix-12, 323 m a.s.l., 4°12′N, 74°39″W, A. Gómez col., 1 ♀ [UNAB]; Natagaima, 10-i-1975, 326 m a.s.l., 3°37′27″N, 75°05′55″W, 1 ♀ [UNAB]; Ortega, Vereda San Roque, 28-iv-2007, L. Cocoma & J. Abarca cols, 1 ♀ [56071 – ICN]. **Valle del Cauca:** La Unión, 30-v-2001, G. Aguado col., 1 ♂ [CEUN]. **No data:** 9 ♀ [AMNH]; 1 ♀ [CEBUC]; 1 ♀ [FSCA]; x-1968, 2 ♀ [LACM]; 1 ♀ [ICN]; 3 ♀ [MNH-Uca].

Remarks

Adults have been found in plantations of mango, *Mangifera indica* L. (Anacardiaceae). They can also be collected using fruit traps or easily caught in flight with an entomological web. Label data indicate that adults have been captured at lights. Specimens have been found from 300 to 2900 m elevation.

Cotinis lebasi (Gory & Percheron, 1833)
(Figures 1M–R and 4)

Gymnetis lebas Gory and Percheron 1833: 334 (original combination)

Diagnosis

Length 21.7 – 34.1 mm; width 14.1 – 18.7 mm. Dorsal surface opaque olive green, velvety (Figure 1M). Frontal projection curved, developed, free at apex, fused 90% to the head, expanded apically into a round disc-like structure (Figure 1N, O). Elytral costae absent. Pronotum and elytra smooth. Males and females with tridentate protibiae, basal tooth reduced. Mesometasternal projection short, with rounded apex (Figure 1P). Surface of pygidium smooth, with some punctures at base (Figure 1Q). Parameres elongate, anterolateral projections forming lobes directed backward (Figure 1R). Internal sac with two long, strong spines.

Distribution

Honduras, Costa Rica, Panamá, and Colombia (Goodrich 1966; Solís 2004).

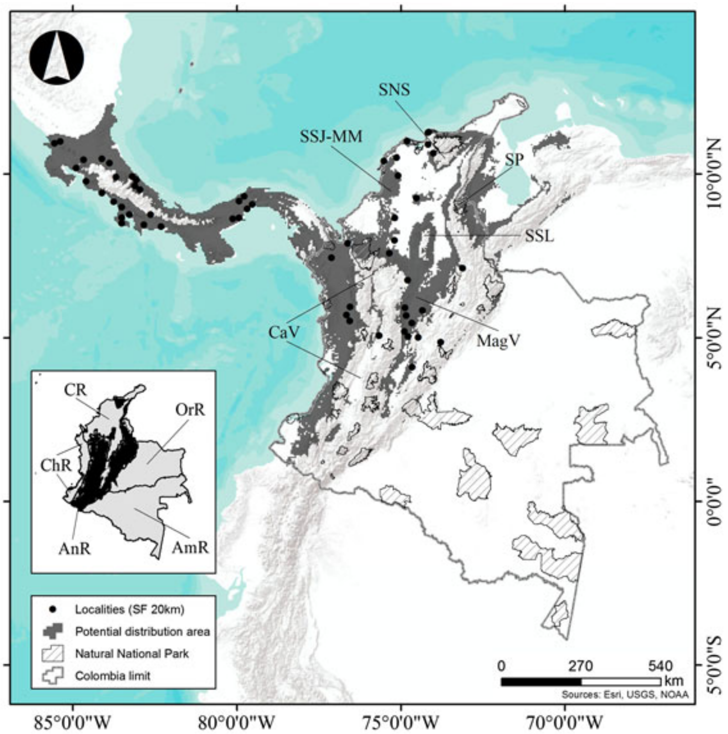

Figure 4. Potential distribution of *Cotinis lebasi* according to threshold "10th percentile training presence." SF 20km = Spatial filter at 20 km. SNS = Sierra Nevada de Santa Marta; SSJ - MM = Serrania de San Jacinto - Montes de María; SP = Serrania del Perijá; SSL = Serranía de San Lucas; MagV = Inter-Andean valley of Magdalena river and CaV = Inter-Andean valley of Cauca river. Inner map: CR = Caribean region; OrR = Orinoquía region; ChR = Choco region; AmR = Amazonas region and AnR = Andean region (black area show the Andean range from 500 m).

Potential distribution model

The potential distribution model of *C. lebasi* shows values for the AUC test =0.71 and ROC Partial test $=1.27 \pm 0.11$ ($p < 0.001$). The model indicates a distribution in humid and very humid tropical forest areas (lowlands), especially along the Chocó – Darién region and Magdalena River valley (Figure 4).

Specimens examined

71 specimens (20 ♂, 51 ♀). **Antioquia:** Apartadó, viii-1981, A. Jaramillo col., 1 ♀ [MEFLG]; Via a Carepa, Parque de los Encuentros, 25-xi-2004, 30 m a.s.l., Velez & Grisales cols, 1 ♀ [7779 - MEPB]; Cáceres, iv-1949, Gallego col., iii-1957, 85 m a.s.l., F. Gallego col., 3 ♀ [MEFLG]; Carepa, 14-vi-2009, A. García col., 1 ♀ [LEBUC]; Caucasia, x-1993, J. V. Delgado col., en cítrico, 3 ♀ [MEFLG]; San Luis, Rio Claro, 28-ii-1994, A. Acosta col., 1 ♂ [4827 – MUJ]; Vegachí, i-1996, 1000 m a.s.l., 6°46′23′N, 74°48′06′′W, F. Yepes col., 1 ♀ [UNAB], no data, i-1943, Gallego col., 1 ♀ [MEFLG]. **Atlántico:** Barranquilla, viii-1941, 68 m a.s.l., in *Gossypium hirsutum* (algodón), 1 ♀ [MEFLG]; Repelón, Bijibana, 10°30′05′′ W, 75°80′01′′W, 170 m a.s.l., H. Beltrán col., 1 ♀ [ICN]. **Bolívar:** Cartagena, no data, 1 ♂ [EIUIC]; San Juan, 1940, 1 ♀

[FSCA]. **Boyacá:** Puerto Boyacá, Puerto Romero, i-2001, 280 m a.s.l., 1 ♂ [ICN]. **Caldas:** La Dorada, 21-v-1977, 178 m a.s.l., 5°27′24″N, 74°40′02″W, L.G. Zapata col., 1 ♂ [UNAB]; Puerto Triunfo, Reserva Natural el Cañón del Rio Claro, 6-iii-2006, 322 m a.s.l., 5°53.6′N, 74°51.4′W, F. Muñoz col., 1 ♀ [MEPB]; R. N. Riomanso, 6-iv-2011, 12-i-2011, Hincapié & Uribe col., 2 ♀ [LEBUC]; Santagueda, 26-iv-2008, Arias García col., 1 ♀ [LEBUC]. **Chocó:** Quibdó, Cgto. Pacurita, 18-24-viii-2003, 48 m a.s.l., 5°41′16″N, 76°39′56″W, D. Quinto col., 2 ♂, 2 ♀ [UNAB], 1 ♂, 1 ♀ [MEFLG]; Lloró, Vda. Peñaloza, Granja UTCH, 04-iv-2002, 90 m a.s.l., 5°30′39″N, 76°32′40″W, E. Martínez col., 1 ♀ [UNAB], 27-xii-2001, J. C. Neita col., 3 ♀ [IEXA]; Peñaloza, Granja Universidad Tecnológica del Chocó "Diego Luis Córdoba", 1-vii-2005, 90 m a.s.l., J. C. Neita col., 2 ♂, 1 ♀ [ICN]; Riosucio, Sautatá – Morafio, 3-iv-1978, Echeverri col., 1 ♂ [39472 – ICN]. **Cundinamarca:** El Peñón, Vda. Guanacas, 27-i-2004, 1856 m a.s.l., A. Morales col., 1 ♀ [UNAB]; Villeta, 03-iv-1977, 804 m a.s.l., 5°00′52″N, 74°28′33″W, E. Quiroga col., 1 ♀ [UNAB]. **Magdalena:** San Fernando, iii-1944, 25 m a.s.l., F. Gallego col., 1 ♀ [MEFLG]; Santa Marta, Parque Nacional Natural Tayrona – Pueblito, 8-viii-1976, 30-viii-1976, 30-x-1976, 1-i-1977, 1-viii-1977, 12-viii-1977, C. C. Kluger col., 2 ♂, 5 ♀ [IAvH, MUSENUV, UNAB, UPTC]; Sevilla, 1941, 1598 m a.s.l., F. Galleco col., 1 ♀ [MEFLG]; Zona Bananera, iii-1943, 1 ♀ [MEFLG]; Río Frío, 28-v-1923, Darlington col., 1 ♂, 4 ♀ [EIUIC]. **Santander:** Bucaramanga, 18-i-1994, 958 m a.s.l., 7°07′17″N, 73°07′33″W, C. R. Bojacá, 1 ♀ [UNAB]. **Sucre:** San Marcos, La Sierpe, 26-vi-2003, 26 m a.s.l., 8°40′N, 75°08′W, J.C. Neita col., 7 ♂, 8 ♀ [UNAB]. **Tolima:** Armero, 05-vi-1980, 352 m a.s.l., 4°57′53″N, 74°54′24″W, F. González col., 1 ♀ [UNAB]; Finca La Ceiba, ix-2003, C. Diego col., 1 ♂, [E-ANDES]; Mariquita, 06-vi-1970, 328 m a.s.l., 5°12′10″N, 74°55′49″W, U. Brigard col., 1 ♀ [UNAB]. **No data**: 1 ♀ [EIUIC]; 1 ♀ [FMNH]; 1 ♀ [MEFLG]; 1 ♂ [UPC].

Remarks

The name of this species was originally written as *Gymnetis lebas* by Gory and Percheron (1833), it was emended to *Cotinis lebasii* by Burmeister (1842), and later changed to *C. lebasi* by Bates (1889). According to Goodrich (1966), the modern ending for a patronym used by Bates (1889) must be adopted.

Adults are diurnal and have been observed on flowers of *Annona muricata* L. or feeding on mature fruits of *Annona chirimoleae* Millar (Annonaceae), *Psidium guajava* L. (Myrtaceae), and *Musa* spp. (Musaceae) (Neita et al. 2006). They can be collected with fruit traps. Larvae have been found in the detritus piles of *Atta colombica* Guerin (Neita et al. 2006). In Costa Rica, larvae have also been found in the waste burrows of *Orthogeomys* sp. (Geomyidae) (Solís 2004). Label data indicate that adults have been collected on flowers of mango and *Rollinia* sp. (Annonaceae). Label data also indicate that several specimens have been collected using black-light traps. Adults have been found from 300 to 1000 m elevation.

Cotinis lebasi is easily distinguished among *Cotinis* species by the frontal projection expanded at the apex into a disc-like structure that can vary in shape. According to Goodrich (1966), populations in Honduras and Costa Rica have a relatively large frontal projection with an expanded apex, while populations in Colombia have a much reduced frontal projection with the apex almost parallel-sided. Several specimens from Panamá resemble the form from Costa Rica, whereas others resemble the form from Colombia, giving rise to a possible zone of intergradation with clinal variation (Goodrich 1966)

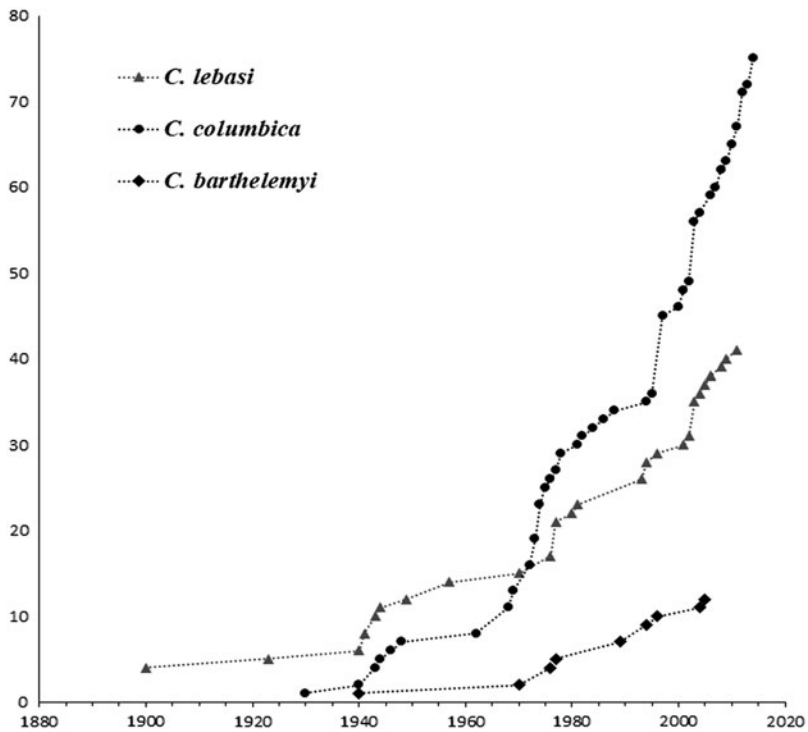

Figure 5. Accumulation records of *Cotinis* for the years 1900–2014 in Colombia.

Key to the adults of Cotinis *species of Colombia*

1 Clypeal projection triangular, reduced to well-developed. Mesometasternal projection short and broad. Surface of pygidium smooth, with some punctures usually at base. Parameres elongate, slender, anterolateral projections forming lobes directed backward (Figure 1L,R), internal sac with two spines.. 2

- Clypeal projection variable, parallel-sided or slightly expanded apically. Mesometasternal projection well-developed. Surface of pygidium with transverse strigulations (Figure 1E). Parameres robust, broad, anterolateral projections developed, forming lobes directed at right angle (Figure 1F), internal sac with a single spine... ***C. barthelemyi***

2 Frontal projection fused to head (Figure 1H). Elytra with two longitudinal costae slightly marked (Figure 1G) .... ***C. columbica***

- Frontal projection curved, well-developed, free at apex, fused 90% to the head, expanded apically into a round, disc-like structure (Figure 1N). Elytral costae absent (Figure 1M) ....***C. lebasi***

Data were taken from 212 specimens collected in 16 departments (states) and approximately 100 municipalities. The departments with the greatest number of records were Cundinamarca (27.5%), Tolima (14.2%), Magdalena (9.5%), Sucre (7.1%), and Caldas (6.2%). Species with highest sampling representation (specimens + localities) was *C. columbica,* followed by *C. lebasi,* and *C. barthelemyi*. Compiled occurrence data include a historical record for a discontinuous period of 114 years of sampling (1900-2014). *Cotinis columbica* has the largest number of records accumulated over time, with

Table 1. Contribution and permutation importance of bioclimatic and geographical variables in the potential distribution models for *Cotinis columbica* and *Cotinis lebasi*. Parameters of the bio-variables with the highest percentage contribution to the models are in bold. The 19 bioclimatic variables are coded from Bio1 to Bio19 (For explanations of biovariables see Table S1).

	% contribution	Permutation importance	% contribution	Permutation importance
Bio1	0.2	0	1.3	0.0
Bio2	0.6	1.3	1.7	2.2
Bio3	0.6	0.1	2.3	4.5
Bio4	1.8	3	**11.6**	**6.3**
Bio5	2.1	6.6	3.8	10.3
Bio6	6.6	1.2	1.0	0.0
Bio7	1.3	0	1.0	2.3
Bio8	0	0	0.0	0.0
Bio9	0	0	2.8	53.7
Bio10	0	0	1.2	0.1
Bio11	0.7	0.3	0.0	0.0
Bio12	0	0	0.0	0.0
Bio13	0	0	**12.7**	**4.7**
Bio14	4.9	0	0.5	1.0
Bio15	7.9	14.7	0.4	0.6
Bio16	7.9	8.9	0.0	0.0
Bio17	0.1	1	8.0	0.0
Bio18	0.1	0.6	0.9	0.0
Bio19	1	0.6	7.1	5.9
Elevation	**21**	**56.9**	**37.7**	**2.8**
Slope	**43.4**	**4.8**	6.0	5.6

an apparent increase in sampling from the 1970s to 2000, while *C. lebasi* has a wider range of historical records, but represented in fewer locations (Figure 5).

Assessment of potential distribution

The Jackknife test for *C. barthelemyi* indicated that available data do not provide a potential distribution model better than would be expected from chance (successes =0.4444; *p* value =0.945971). Therefore, a potential distribution model for this species is not presented.

Among environmental variables, elevation was the variable with greatest contribution to the *C. lebasi* model (37.7%) and the second most influential variable in the *C. columbica* model (21%) (Table 1). Bio4 (Temperature Seasonality) and Bio13 (Precipitation of Wettest Month) showed a joint contribution of 24.3% for the *C. lebasi* model. For the *C. columbica* model, the slope was the variable that contributed most to the model (43.4%) (Table 1).

The overlap of potential distribution areas with the National System of Protected Areas of Colombia (∼11`399.222 ha) was less than 8% (*C. lebasi*: 2.39%, *C. columbica*: 7.37%). The potential distributions of both species have an overlapping area that includes the foothills of the Andean external slopes (Chocó and Amazon-Orinoquia) and the inter-Andean valleys of the Cauca and Magdalena Rivers. At the species level, this overlapping area corresponds to 21.25% and 26.86% of the potential distribution areas of *C. lebasi* and *C. columbica*, respectively.

Discussion

The present study represents the first taxonomic and geographic consensus for *Cotinis* in Colombia. The potential distribution analysis of occurrence data suggests a low spatial co-occurrence among *Cotinis* species in Colombia. Our model suggests that *C. columbica* is an Andean species, exceeding altitudes of 2500 m and with potential distribution in the internal slope of the Cordillera Oriental, Cordillera Central, and the internal slope of the southern Cordillera Occidental. The areas of potential distribution coincide with transitional inter-Andean ecosystems between dry forest and pre-montane humid forest south of the Magdalena and Cauca Rivers (Figure 3). These areas are characterized by high levels of forest fragmentation due to agricultural activities. It is important to highlight that potential distribution analysis suggests that *C. columbica* could be present in the Serranía de San Lucas (Figure 3), one of the least sampled areas due to difficult access and problems of public order.

Cotinis lebasi has potential distribution in areas of humid and very humid tropical forest (lowlands) (Figure 4). In particular, this species has a potential distribution in the rainiest areas of the Chocó – Darién province (Tropical wet zonobioma of Baudó – Darién and Pacific) (Ideam et al. 2007; Morrone 2014). These results are consistent with the observed presence of *C. lebasi* in the wet, tropical forest of central Panama and the Pacific coast of Costa Rica (Solís 2004).

Although the potential distribution model for *C. barthelemyi* did not yield significant results, we can infer based on occurrence data, that this species may be associated with environmental conditions of lowlands of the Caribbean region and the northern valley of the Magdalena River. These areas correspond to dry forest biomes with high anthropic disturbance in Colombia (Pizano and García 2014).

Colombian *Cotinis* species can be considered rare in the inventories that include broad-spectrum capture methods; therefore, specimens are relatively few in entomological collections. Although the scarcity of records may reflect a deficiency in historical sampling, it is also possible that such rarity is due to the narrow environmental requirements of these species. According to data compiled in the synopsis, the incidence of the species may depend on the availability of suitable substrates for oviposition by females, food resources, or humid and warm environments. This situation is distinctive in Cetoniinae, as adults are usually found feeding on juicy fruits, nectar in flowers, and plant exudates. Larvae are generally found in rotten trunks, among the roots of epiphytes or in tree holes, under dry dung pats, in living tissue of bromeliads, or in detritus piles of ants nests or decomposing organic material of the waste burrows of rodents (Deloya 1988; Krell and Simon 2002; Orozco and Pardo-Locarno 2004; Solis 2004; Neita et al. 2006; Orozco 2012a; Puker et al. 2014).

Less than 8% of the potential distribution areas for *C. lebasi* and *C. columbica*, overlaps with the National System of Protected Areas. This coincides with studies for other animal groups in Colombia (e.g. birds: Franco et al. 2007, reptiles: Carvajal-

Cogollo and Urbina-Cardona 2008, butterflies: Constantino 2007). This situation may be due in part to the fact that most of the data come from collections outside of national parks or from areas that would not have the bioclimatic conditions that *Cotinis* species require. However, the latter should be taken with caution. This underscores the need for increased sampling to improve potential distribution models by expanding the geographical representativeness of occurrence data.

According to our distribution models, the overlapping of *C. lebasi* and *C. columbica* corresponds approximately to 1/5 of their potential distribution areas. The models suggest that both species may be sympatric in areas considered as transition zones between dry forest, tropical and subtropical forest, and Andean cloud forest (Andean foothills, Caribbean valley, surroundings of Serranía del Perijá, Serranía de San Lucas and Urabá-Antioquia region). These zones are priorities for conservation because of their high diversity and endemism, and their inclusion in the National System of Protected Areas (Dávalos 2001; Armenteras et al. 2003; Vásquez and Serrano 2009; Romero-Ruiz et al. 2013; Aldana-Domínguez et al. 2017). Therefore, it is possible that these transition zones should be considered for future biological inventories, due to their environmental vulnerability and incipient biodiversity information.

Similar critical scenarios, with very little occurrence data in Colombia, can be observed in other species of Gymnetini (Cetoniinae) such as *Gymnetis pantherina* Burmeister, 1842, *Gymnetis stellata* (Latreille, 1813) (Suárez and Amat-García 2007), *Euphoria abreona* Janson, 1878, *Euphoria hera* Burmeister, 1842 (Orozco 2012b), *Amithao lafertei* (Thomson, 1860), *Amithao decemguttatus* (Waterhouse, 1876) (Ratcliffe 2013a), *Desicasta reichei* (Thomson, 1860) (Ratcliffe 2013b), *Hoplopyga foeda* (Schaum, 1848), *Hoplopyga ocellata* (Gory & Percheron, 1833) (Shaughney and Ratcliffe 2015), *Allorrhina carmelita* (Burmeister, 1842), *Allorrhina scabriuscula* (Swederus, 1787), and *Allorrhina soror* Moser, 1911 (Ratcliffe 2015).

Recent studies suggest that in the tropics there are scant geographical surveys of Scarabaeoidea (Sanabria-García et al. 2012; López-García et al. 2015), even in groups with a long history of inventories and ecological study, such as dung beetles (e.g. Cultid-Medina et al. 2014). This work represents a first effort to complement previous taxonomic work by using the geographic information available from entomological collections of Neotropical Cetoniinae. Thus, we suggest that this type of analysis could be implemented for other Scarabaeoidea genera or subfamilies in Colombia. In this way, not only will taxonomic synopses be obtained, but also, it will be possible to evaluate the temporal and spatial representativeness of collection data across different scales.

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Disclosure statement

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Supplementary material

Supplemental data for this article can be accessed here.

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