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ORIGINAL ARTICLE

Confirmation of the presence of Crab-eating Raccoon *Procyon cancrivorus* (Procyonidae) in the Colombian Amazon, hypothesis of distributional area, and comments on juvenile specimens

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Abstract.
In Colombia, the Crab-eating raccoon *Procyon cancrivorus* is distributed in the Andes, Caribe, Chocó, and the Orinoco regions, from sea level up to 2500 m. Although its presence in the Amazon region is probable, based on records of adjacent countries such as Ecuador, to date, there are not verified records from this region in Colombia. In this work we report a juvenile male specimen from Villa Garzón, Department of Putumayo, Colombia. This record corroborates the presence of the taxon in the Colombian Amazon. Considering previous distributional maps in Ecuador and Colombia, our data increased the range of this species to zones in the Magdalena Valley and Amazon regions of Colombia, Andes mountains and Pacific of Ecuador and Colombia. Based on additional juvenile specimens deposited at Colombian collections, we describe some external and cranial characters.

Keywords: Crab-eating raccoon, conservation, distributional records, new locality, range increase.

Confirmación de la presencia de *Procyon cancrivorus* (Procyonidae) en la región de la Amazonía colombiana, nueva hipótesis de área de distribución y comentarios sobre individuos juveniles

Resumen.
En Colombia, el Mapache cangrejero *Procyon cancrivorus* se distribuye en los Andes, el Caribe, el Chocó, y la región de la Orinoquía en un rango altitudinal comprendido entre los 0 y 2500 m. Aunque la presencia de la especie en la Amazonía de Colombia es probable, con base en registros de localidades de países vecinos como Ecuador, hasta el momento se desconocen de registros verificados provenientes de esta región. En el presente trabajo registramos un ejemplar juvenil macho proveniente de Villa Garzón, departamento del Putumayo, Colombia. Con este registro corroboramos la distribución geográfica de este taxón en la Amazonía colombiana. Considerando el área de distribución propuesta previamente para la especie en Ecuador y Colombia, la nueva área de distribución se incrementó a zonas en los Andes y Pacífico de Colombia y Ecuador, y el Valle del Magdalena y Amazonía Colombiana. A partir de ejemplares juveniles adicionales depositados en colecciones colombianas, describimos algunos caracteres externos y craneales.

Palabras clave: conservación, incremento del rango, mapache cangrejero, nueva localidad, registros de distribución

The genus *Procyon* comprises three species: the Cozumel Raccoon *Procyon pygmaeus*, endemic to Cozumel Island; the Northern Raccoon *Procyon lotor*, and the Crab-eating Raccoon *P. cancrivorus* (Helgen & Wilson 2005). In South America, two species have been reported: *P. lotor*, distributed in the Caribbean region of Colombia and probably Venezuela (Helgen & Wilson 2005, Marín *et al.* 2012, Helgen *et al.* 2013), and *P. cancrivorus*, which extends in South and Central America from Panama to Northern Argentina (13,254,551 km^2; Reid & Helgen 2008).

The distribution of Crab-eating Raccoon *P. cancrivorus* in Colombia and Ecuador have been recently updated, including available records from different regions of these countries, on an elevational range from sea level to 2,350 m asl (Marín *et al.* 2012). In these countries, the species is widely distributed; however no records from the Amazon region of Colombia are available (Marín *et al.* 2012), but its presence in this region was suggested by Reid & Helgen (2008). In this communication, we introduce verified records of *P. cancrivorus* from one locality of the Colombia Amazon, corroborating the presence of the species in this area. In addition, we updated the distribution map for the species in South America, based on the inclusion of recent records from Colombia and Ecuador available in literature.

Confirmed record from the Colombian Amazon

Two young male individuals from a litter were rescued on December 2011, after the mother was killed by a domestic dog, in Villa Garzón, Department of Putumayo, near to Caucayá river (0º 3′ N, 75º 2′ W, 212 m asl), in the Colombian Amazon. Both animals were taken to the Centro Experimental Amazonico in Mocoa, Putumayo, to provide them food and care. Both individuals survived for 95 days. Only the skin of one of them was preserved and deposited at the Biological Collection of the University of Nariño (MUN). The specimen (MUN 0635) was preserved as skin and presents the following external measurements: total length 404 mm, tail 104 mm, foot 58 mm, and ear 28 mm. We reviewed one skin of a young male of *P. cancrivorus* (Figure 1).

Hypothesis of distributional area

We compiled a database with 45 geo-referenced records of *P. cancrivorus* from Colombia and Ecuador. The database included the records provided by Marín *et al.* (2012), the new record of this study (Figure 1), and others as indicated in the Table 1.

In this study, we use the species distribution modelling program MAXENT (ver. 3.3.3e; Phillips *et al.* 2006) to predict the distribution of *P. cancrivorus*. MAXENT integrates environmental data with species locality information to give a relative measure of suitability across a study area (Phillips *et al.* 2006). Because models using only presence data can be affected by spatial autocorrelation, we applied a spatially filtering locality analysis considering the climate heterogeneity (Veloz 2009, Boria *et al.* 2014). We used 39 localities from the 45 localities to the construction of the model.

For environmental data, we used a set of eight uncorrelated (Pearson’s correlation coefficient $r > 0.7$) bioclimatic variables, some of which could reasonably be assumed to affect species ecology: Annual mean temperature, mean diurnal range, temperature seasonality, mean temperature of coldest quarter, annual precipitation, precipitation of wettest month, precipitation of driest month and precipitation of warmest quarter. Climate variables were obtained from the WorldClim database (www.worldclim.org ver. 1.4, Hijmans *et al.* 2005) at a resolution of 1 km^2. All environmental data were standardized to geographic coordinates (Datum WGS-1984). We developed 25 replicate models for *P. cancrivorus* based on bootstrapped subsamples of available occurrence data, 25% of random test points and maximum background 60,000.

Table 1. Records of *P. cancrivorus* from Colombia and Ecuador used for the new map of distribution. The marks (*) indicate the excluded records.

	Dept./Prov.	Rec.	Locality	Latitude	Longitude	Source
COLOMBIA	Antioquia	1	Puerto Berrío	6°29′ N	75°24′ W	1
		2	Medellín, Corregimiento de Santa Elena, vereda Chorroclarín, 2,350 m asl	6°13′ N	75°29′ W	1
		3	Frontino	6°47′ N	76°7′ W	1
		4	Puri, above Caceres	7°49′ N	75°12′ W	2
		5	Valdivia	7°16′ N	75°24′ W	2
	Bolívar	6	San Juan Nepomuceno	9°54′ N	75°6′ W	2
		7	Cartagena	10°31′ N	75°30′ W	1
	Caldas	8	Victoria, vereda El Llano, Finca Sabanilla, 312 m asl	5°19′ N	74°54′ W	1
		9	Norcasia	5°34′ N	74°53′ W	1
		10	Manizales, Corregimiento el Manantial, Vereda Espartillal, 1,950 m asl	5°7′ N	75°28′ W	1
	Cauca	11	Río Saija, La Boca	2°43′ N	77°28′ W	1
	Casanare	12	Orocué	5°8′ N	71°30′ W	1
	Cesar	13	La Jagua de Ibirico, Corregimiento de la Victoría de San Isidro, Veredas Alto de las Flores and the Zumbador.	9°32′ N	73°19′ W	3
	Chocó	14	Riosucio, PNN Katíos, right margin of Peye River, Peye zone.	7°48′ N	77°8′ W	1
		15	Río Sucio, PNN Katios, vereda Sautata, left margin of Atrato River, 100 m of the cabin.	7°48′ N	77°8′ W	1
		16	Ungia	8°7′ N	77°5′ W	2
	Córdoba	17	Socorro, upper Río Sinú	8°35′ N	75°54′ W	2
	Cundinamarca	18	Bogotá	4°36′ N	74°4′ W	1
		19	El Triunfo, near to Viotá	4°30′ N	74°28′ W	1
	La Guajira	20	La Guajira	11°21′ N	72°31′ W	Footprints
	Huila	21	Villavieja	3°12′ N	75°14′ W	1
	Magdalena	22	PNN Isla de Salamanca	10°59′ N	74°31′ W	1
		23	Cerro de San Lorenzo, Sierra Nevada de Santa Marta, 1900 m	11°4′ N	73°59′ W	1
		24	*PNN Isla de Salamanca, Km 5 carretera Barranquilla-Ciénaga	10°59′ N	74°42′ W	1
		25	*PNN Isla de Salamanca, Km 16-17 carretera Barranquilla-Ciénaga	10°59′ N	74°35′ W	1
		26	PNN Isla de Salamanca, Los Cocos	10°59′ N	74°31′ W	1
		27	Santa Marta	11°14′ N	74°6′ W	1
		28	*Pueblo Viejo, Vía Parque Isla de Salamanca	10°58′ N	74°30′ W	4
		29	Pueblo Viejo, Santuario de Fauna y Flora de la Ciénaga Grande	10°50′ N	74°24′ W	4
	Nariño	30	Tumaco, Santa María	1°40′ N	78°39′ W	1
	Santander	31	Bucaramanga, vereda Vijagual	7°11′ N	73°3′ W	Photographs
	Sucre	32	Tolú, Caño Francés	9°32′ N	75°34′ W	1
		33	Coloso, Las Campanas	9°32′ N	75°22′ W	2
	Tolima	34	Ibagué, km 10, road from Ibagué to Bogotá	4°23′ N	75°10′ W	1
	Putumayo	35	Puerto Garzón, near to Caucayá river,	0°4′ N	75°2′ W	New record
			Department of Valle del Cauca			
		36	Buenaventura, San Miguel, Río Naya	3°26′ N	76°35′ W	1
ECUADOR	Manabí	37	Manabí, between Bahía de Caraquez and Pedernales	0°35′ S	80°21′ W	1
	Morona Santiago	38	Arapaicos, near to Macas	0°14′ S	78°31′ W	
	Napo	39	El Reventador	0°5′ S	77°39′ W	
		40	Avila Viejo	0°36′ S	77°30′ W	
	Orellana	41	Loreto, San José de Payamino, 300 m asl	0°30′ S	77°16′ W	
		42	Loreto, Cotapino river, Alto Napo	0°33′ S	77°47′ W	
		43	El Cristal, near to Auca	4°7′ S	79°12′ W	
	Oro	44	Arenillas, Reserva Militar Arenillas	3°28′ S	80°13′ W	
		45	*Arenillas, Destacamento Cayancas, estero Viernes Santo 'Las Tomateras'	3°28′ S	80°9′ W	

Sources: 1: Marín *et al.* 2012, 2: SiB Col 2014, 3: Ramírez 2009, 4: Moreno-Bejarano & Álvarez-León 2003; SiB Col = *Sistema de información sobre Biodiversidad de Colombia.*

We measured the accuracy of the MAXENT models using the Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve, which is a threshold-independent measure of a model's ability to discriminate between absences and presences (Fielding & Bell 1997). Models with AUC > 0.75 for both training and test data were accepted, but the average model was retained for the analysis. Logistic model selected was transformed to boolean layers (*i.e.*, presence-absence) with a cut-off threshold equal to the minimum training presence (Pearson *et al.* 2007), which sets the threshold at the lowest value of the prediction for any of the presence localities in the calibration dataset. Finally, we estimated the distributional area of *P. cancrivorus* in Ecuador and Colombia.

Figure 1. Specimen of Crab-eating Raccoon *Procyon cancrivorus* from Villa Garzón, Putumayo (Colombia).

Of the 45 localities, 36 were presence records from Colombia and nine localities from Ecuador (Figure 2). The distributional model (training AUC = 0.9, test AUC = 0.8; cut-off threshold = 0.1) of *P. cancrivorus* predicted an area of 1,480,685 km^2 for Colombia and Ecuador (Figure 2). In comparison with the previous distribution map (see Reid & Helgen 2008), the new one increased the area of distribution in 469,810 km^2 (32%; Figure 3). Here the distributional area of *P. cancrivorus* was extended to zones in the Magdalena Valley and Amazon regions of Colombia, Andean mountains and Pacific of Ecuador and Colombia (Figure 2). The model predicted low suitable habitat in Colombian Llanos of the Orinoco region.

The presence of Crab-eating raccoon in Colombian Amazon was inferred by Marín *et al.* (2012) based on records from Ecuador; the new record presented here (Figure 1) corroborates this assumption. The new locality (Villa Garzón) is characterized by the presence of tropical wet forest and other habitats near of rivers and streams; these habitats have been suggested as suitable for the species (Emmons & Feer 1999, Tirira 2007, Arispe *et al.* 2008).

A recent distributional map of *P. cancrivorus* excluded part of the Andes and Chocó regions in Colombia and Ecuador (Reid & Helgen 2008), from which there is available extensive evidence of its presence (see Marín *et al.* 2012). The records and the distributional model indicate that *P. cancrivorus* has a wide distributional area, that probably may be associated with the generalist habits and high tolerance to human-disturbed environments. In these areas *P. cancrivorus* can use garbage and exotic species as food resources (Gatti *et al.* 2006). This pattern has been also observed in *P. lotor* for which its movements and spatial distribution are affected for anthropogenic food resources

(Prange *et al.* 2004). Probably the distribution of *P. cancrivorus* is affected by the human settlements (*e.g.*, towns, cities), but ecological analyses are necessary to test whether urban ecosystems may represent a new available habitat for the species' range expansion or contraction. The new map of distribution of *P. cancrivorus* is a large scale hypothesis which could be employed to regional analysis, but local analysis needs of more accuracy.

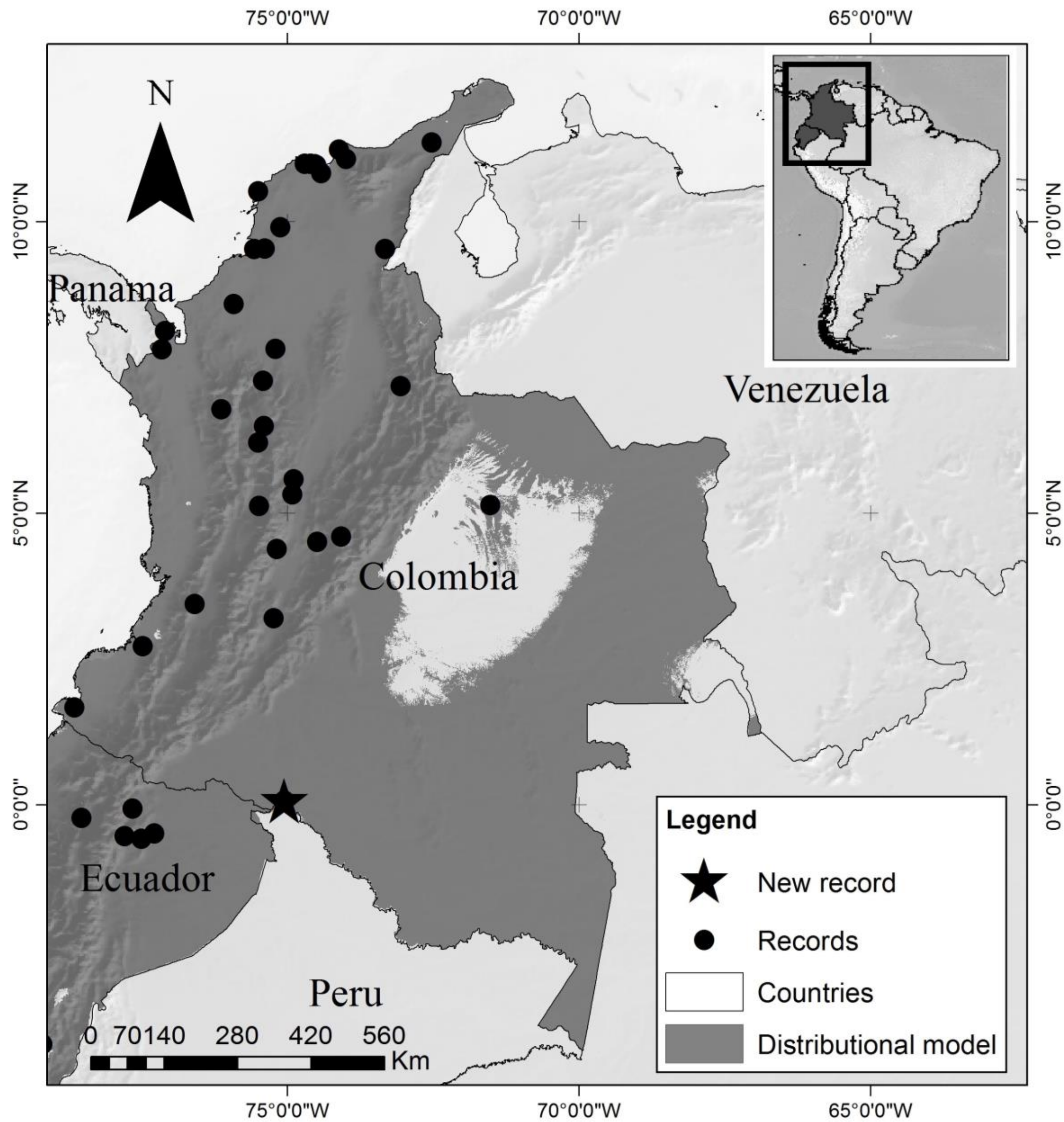

Figure 2. Records of Crab-eating Raccoon *Procyon cancrivorus* in Colombia-Ecuador modified from Marín *et al.* 2012 (black circles). The locality of the new record from Amazonas region of Colombia (black star) and its potential distribution obtained with MAXENT.

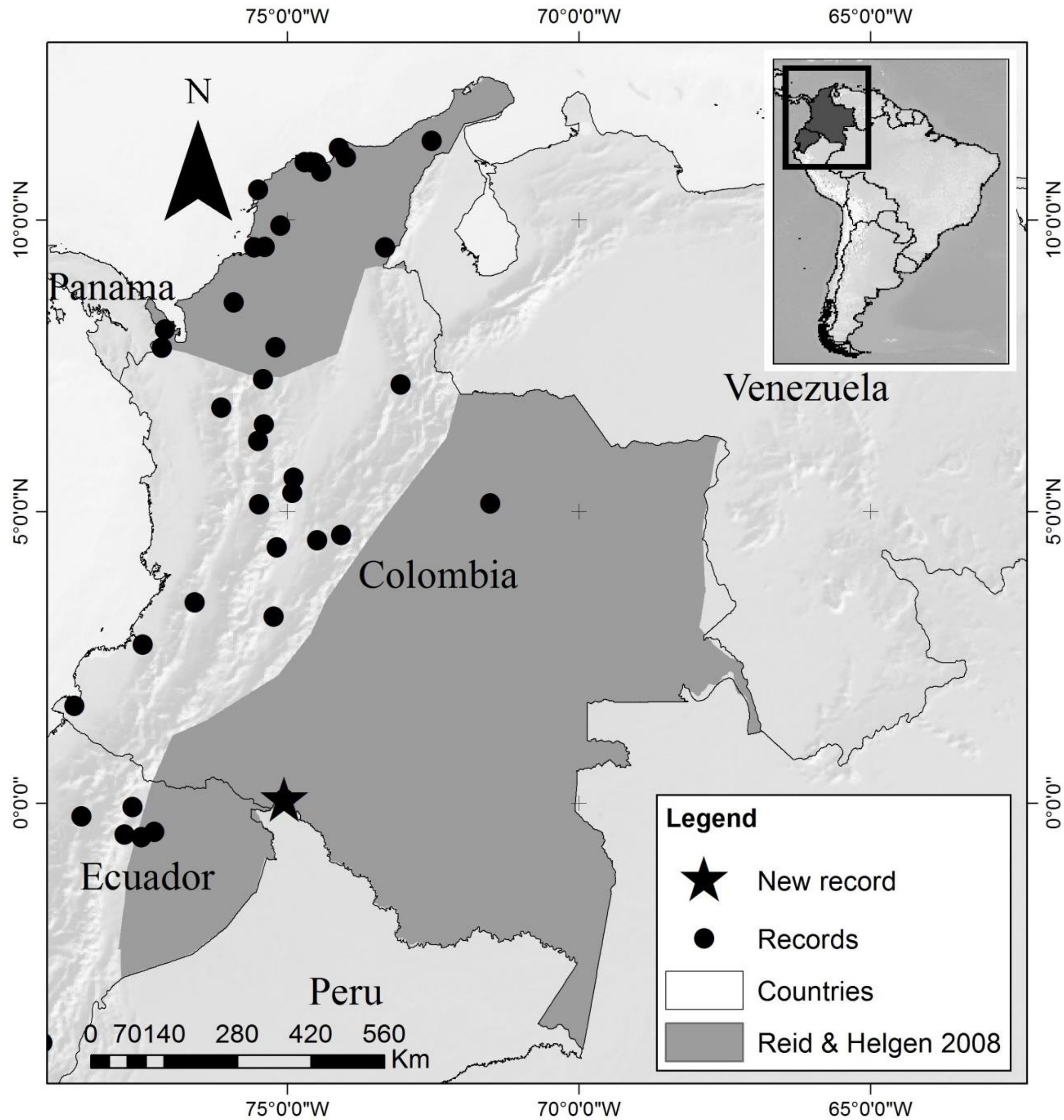

Figure 3. Updated distribution of the Crab-eating raccoon in Colombia and Ecuador. Shaded area shows the distribution suggested by Reid & Helgen (2008) in these countries.

The model of potential habitat indicates that in the Andean highlands there are favourable environmental conditions for the colonization of *P. cancrivorus*, however, the records from elevations over 2,350 m were absent. More information is necessary about the habitat requirements and behaviour of the *P. cancrivorus* in the Andean mid and high-lands.

Comments on juvenile specimens from Colombia

Due the scarcity of information regarding to juvenile specimens from Colombia, external characters of both juvenile individuals from the Amazon region of Colombia are described herein. At the time of rescue (Figure 1) both individuals exhibited mixed short brown and long white hairs (mantle); the head was white with a small black mask around the eyes, ears relatively short and whitish. Blackish dorsum, interspersed with gray, and grayish ventral region. After 95 days, changes in the coloration were observed: Head and ears became blackish with cinnamon hairs, and the black mask around the eyes became broader but still ambiguous in the nose, in comparison with adult specimens. The dorsum became darker, with dark brown and yellowish hairs; the ventral region orange. The tail exhibited black rings poorly defined in both stages.

We found six juvenile specimens deposited at the Instituto Alexander von Humboldt (IAvH), Villa de Leyva, and Instituto de Ciencias Naturales, Universidad Nacional de Colombia (ICN), Bogotá. Two females (IAvH 345, IAvH 346) were collected at Department of Magdalena, Isla de Salamanca on 1 December 1969. The skulls lack of post-orbital process; upper and lower molars not erupted, upper incisors trilobulated, and upper canines procumbent. Lower incisors bilobulated, and lower canines peg-liked. Based on the early development of the deciduous teeth series, we assume that these specimens were likely only nursing.

Two additional females (IAvH 3080, IAvH 3091) were collected at Department of Chocó, Ríosucio, Parque Nacional Natural Katios, left margin of Río Peye on 12 August 1976. The skull of the specimens are similar to those describe above (IAvH 345, IAvH 346), however, the lambdoidal crest is slightly developed and the permanent canines and second upper premolar are erupting. The second upper molar is almost completely erupted but slightly inclined. Lower first molars enlarged (almost the same size of adult specimens). Finally, two juveniles, one male and one female, collected at Department of Casanare, Orocué (ICN 787, ICN 788) on April–May 1959, are larger than previous specimens described above and exhibit upper incisors, canines, premolars and first upper molars erupted.

The fact that two cubs were rescued as well that all juvenile specimens are in groups of two for each locality provided some information about the litter size and periods of reproduction of *P. cancrivorus* in Colombia. We found no information about litter size of *P. cancrivorus* from Colombia, however, the species has a reduced litter size (three per litter in Brazil; Forero-Medina *et al.* 2009), in comparison with *P. lotor* (Mugaas *et al.* 1993) in which mean litter size in different samples from North America range from 1.9 to 5.0 (Lotze & Anderson 1979).

In general, little is known about the ecology and natural history of Crab-eating raccoon and other small carnivores of Colombia, and it is necessary to develop research on those topics.

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