

The genus *Chironius* (Serpentes, Colubridae) in Paraguay: composition, distribution, and morphology

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Chironius is a genus of slender snakes adapted to a diurnal and arboreal life style, and is distributed from Honduras to Uruguay inhabiting different environments. Five species are present in Paraguay: *C. bicarinatus*, *C. exoletus*, *C. flavolineatus*, *C. maculoventris*, and *C. quadricarinatus*. In this work, we provide data on distribution, coloration, and morphological variation of 20 Paraguayan specimens housed in scientific collections. Our results fit with known parameters for the species referred in literature. A conclusion of this work is that, based on distribution and ecological preferences of the species in the region, Paraguay is poorly sampled. Here we extend the known pholidosis range of ventral scale for females of *C. bicarinatus* (154-170), and for *C. maculoventris* (143-157 for females and 154-161 for males), and the range of subcaudal scales for males of *C. maculoventris* (90-125), and females of *C. quadricarinatus* (91-123).

Key words: morphological variation; Neotropical region; pholidosis; sexual dimorphism.

El género *Chironius* (Serpentes, Colubridae) en Paraguay: diversidad, distribución y morfología. *Chironius* es un género de serpientes gráciles adaptadas a un modo de vida diurno y arbórea, que se distribuye desde Honduras hasta Uruguay habitando diferentes ambientes. En Paraguay están presentes cinco especies: *C. bicarinatus*, *C. exoletus*, *C. flavolineatus*, *C. maculoventris* y *C. quadricarinatus*. En este trabajo se aportan datos acerca de la distribución, coloración y variación morfológica de 20 especímenes de Paraguay depositados en colecciones científicas. Los resultados se ajustan a los parámetros conocidos para las especies referidos en la literatura. Una de las conclusiones del presente trabajo es que, de acuerdo a la distribución y a las preferencias ecológicas de las especies a nivel regional, Paraguay está pobremente muestreado. Ampliamos los rangos conocidos de foliosis en lo referente a escamas ventrales para hembras de *C. bicarinatus* (154-170) y para *C. maculoventris* (143-157 para hembras y 154-161 para machos), y en lo relativo a escamas subcaudales para machos de *C. maculoventris* (90-125) y hembras de *C. quadricarinatus* (91-123).

Key words: dimorfismo sexual; rango de foliosis; región Neotropical; variación.

Chironius is a colubrid snake genus of slender aspect with head well differentiated from the body, rounded pupil, and aglyph dentition with maxillae holding 25 to 46

teeth (CHIPPAUX, 1986). These snakes have both arboreal and diurnal habits (MARTINS *et al.*, 2008) and thus show some anatomical adaptations for that lifestyle such as long

tail, big eyes, and the ability to move quickly to allow themselves to thrive in these types of environments (CEI, 1993). Although PINTO *et al.* (2008) and PALMUTI *et al.* (2009) stated that is a snake specialized in the ingestion of anurans, YANOSKY *et al.* (1996) documented this genus also feeding on lizards.

The genus has a wide distribution range, from Honduras in Central America to northern Argentina, Uruguay and southern Brazil in South America (TIPTON, 2005), inhabiting areas of forest, grassland and open xerophytic environments. Snakes of this genus are usually poorly known because they appear infrequently in herpetological inventories (e.g. STRUSSMANN & SAZIMA, 1993; YANOSKY *et al.*, 1996; MARQUES *et al.*, 2000; PALMUTI *et al.*, 2009) being its occurrence lower in dry than in rainy seasons (MARQUES *et al.*, 2000).

KOK (2010) recognized the presence of 21 species belonging to this genus. LINNAEUS (1758) described the three first species: *C. carinatus*, *C. exoletus*, and *C. fuscus* under the genus *Coluber*. FITZINGER (1826) described the genus *Chironius* to include aglyph colubrid snakes with 10 or 12 scale rows around the body and simple hemipenis. DIXON *et al.* (1993) provided additional synapomorphies. In a recent study, HOLLIS (2006) confirmed the strong monophily of the group, and also provided information improving the systematic of the genus, rising to specific status some taxa previously assigned to subspecies.

In Paraguay, three species have been traditionally considered, *Chironius bicarinatus*, *C. flavolineatus*, and *C. quadricarinatus* (AQUINO *et al.*, 1996; GIRAUDO, 2001; MOTTE *et al.*, 2004; CACCIALI, 2009), with two sub-

species of *C. quadricarinatus*, *C. q. quadricarinatus* and *C. q. maculoventris*, that were further raised to the species status by HOLLIS (2006). Additionally, *C. laevicollis* was also documented in Paraguay (specimen ZIMH 677 of the Zoologisches Institut und Zoologisches Museum of Hamburg) by DIXON *et al.* (1993). Nevertheless, those same authors doubt about the validity of that record, saying that there would be a mistake in the locality data, and then is not considered a valid species for the herpetofauna of Paraguay.

DIXON *et al.* (1993) presented detailed information about the morphology of the species of this genus. Since then, GIRAUDO (2001) updated the morphological information for specimens from Argentina, and CARREIRA *et al.* (2005) and CARREIRA & MANEYRO (2013) did similar revisions for Uruguay. In this work, we review the genus *Chironius* from Paraguay, providing data about color variation, pholidosis, and distribution of each species, indicating their habitat preferences. We document new pholidosis ranges for some species.

MATERIALS AND METHODS

For this work, we examined 20 specimens housed in the following collections: British Museum of Natural History (BMNH – London, England), biological collection of the Itaipí Museum-Reptiles (CBMI-R – Hernandarias, Alto Paraná, Paraguay), zoological collection of the School of Exact and Natural Sciences, National University of Asunción (CZ – San Lorenzo, Paraguay), National Museum of Natural History of Paraguay (MNHNP – San Lorenzo, Paraguay), and United States National Museum (USNM – Washington

MORPHOLOGICAL VARIATION IN PARAGUAYAN *CHIRONIUS*

Table 1: List of examined specimens with indication of their reported origin, sex (F: female, M: male), and some pholidosis data. VENT: ventral scales, SC: subcaudal scales. D: damaged specimen, scale counting not possible. Refer to text for details about the museum collection codes. Numbers in bold indicate values out of the previously known pholidosis ranges. The asterisk (*) indicates the holotype for the corresponding species.

Species	Specimen	Sex	Reported origin	VENT	SC	SC / VENT
<i>C. bicarinatus</i>	CBMI-R 60	F	Alto Paraná	168	127	0.756
	USNM 253552	F	Itapúa: El Tirol	170	134	0.788
<i>C. exoletus</i>	CBMI-R 86	M	Alto Paraná	156	150	0.962
<i>C. flavolineatus</i>	BMNH 85.9.1.9	F	Paraguay	159	126	0.792
	MNHNP 5201	M	Amambay: Parque Nacional Cerro Corá	146	130	0.890
	USNM 342095	M	Amambay: Parque Nacional Cerro Corá	148	138	0.932
<i>C. maculovenstris</i>	MNHNP 3167	F	Presidente Hayes: Hacienda Tinfunqué	157	109	0.694
	MNHNP 5226	F	Boquerón: Route IX, km 472	154	103	0.669
	MNHNP 5480	F	Rancho Carandá	143	108	0.755
	CZ 512	M	Rancho Carandá	155	115	0.742
	MNHNP 2504	M	Alto Paraguay: Madrejón	154	90	0.584
	MNHNP 2505	M	Alto Paraguay: Madrejón	155	109	0.703
	MNHNP 3782	M	Route IX, km 343	157	97	0.618
	MNHNP 9252	M	Paraguay	153	D	-
	MNHNP 10016	M	Pozo Colorado	161	122	0.758
<i>C. quadricarinatus</i>	MNHNP 2503	F	Central: Asunción	154	91	0.591
	MNHNP 5479	F	Concepción: Rancho Z	151	119	0.788
	MNHNP 11699	F	Laguna Blanca	151	120	0.795
	MNHNP 10900	M	San Pedro: Estancia Pedernal	144	129	0.896
	USNM 5813*	M	Paraguay	148	> 80	-

DC, USA). The list of examined specimens is shown in Table 1.

Meristic characters of cephalic pholidosis were preocular scales (PRO), postocu-

lar scales (POO), anterior and posterior temporal scales (TEMP), supralabial scales indicating between parentheses which ones are in contact with the orbit (SL), and

infralabial scales indicating between parentheses which ones are in contact with genial scales (IL). Paired structures are shown in left / right order. Damage in pholidosis is indicated with a "D".

In body pholidosis we counted the scale rows around the mid-body, identifying also reduction in one-head length behind the neck, and one-head length before the vent (DOR), ventral scales (VENT) following DOWLING (1951), and subcaudal scales (SC) without including the pair of preloacal plates nor the apical tip. When hemipenis were not everted, sexual identification was made by an incision in the tail.

Because the low number of Paraguayan specimens, it was not possible to apply a statistical test to determine significant differences among species.

Coloration was described upon field notes and photographs of alive animals, with exception of *C. bicarinatus*, for which coloration description was based only in preserved specimens.

A distribution map of each species was created, based on the Paraguayan ecoregions, in order to know the ecological and ecoregional affinities of each species. With this purpose, we used the map of ecoregions based on DINERSTEIN *et al.* (1995). Plots of distribution maps were done using ArcGis 10.

RESULTS

Chironius bicarinatus (Wied, 1820). Two females. DOR 12 / 12 / 10 and 13 / 12 / 12, VENT 168-170, and SC 127-134; ratios SC / VENT 0.75-0.78; PRO and POO always 1 / 1 and 2 / 2, respectively; TEMP 1 + 1 / 1 + 1 and 2 + 1 / 2 + 2; SL 9 (4-6); IL usually 10 (1

-6) except for the left side of female specimen USNM 253552, where it was 9 (1-5). Four to five dorsal scales keeled. Coloration of adult (CBMI-R 60) and juvenile (USNM 253552) specimens fits with those described by DIXON *et al.* (1993) and GIRAUDO (2001). The species is distributed in Alto Paraná and Itapúa Departments, being restricted to the Alto Paraná Atlantic Forest (Fig. 1). BERTONI (1939) recorded this taxon in Puerto Bertoni, and GIRAUDO (2001) in Ciudad del Este, both in Alto Paraná Department. In this area occur the highest and most moist forests of Paraguay, following this ecoregion the course of Paraná River.

Chironius exoletus (Linnaeus, 1758). One male with damaged head. DOR 12 / 12 / 08, VENT 156, and SC 150; ratio SC / VENT 0.96; PRO 1 / 1, and POO 2 / 2; TEMP, SL, and IL damaged. Two paravertebral rows of keeled scales. Even when the specimen is damaged and dehydrated, it is possible to see the coloration, which coincides with color description of GIRAUDO (2001). The only specimen known came from Itaipú Reserve in Alto Paraná Atlantic Forest (Fig. 1).

Chironius flavolineatus (Jan, 1863). One female and two males. DOR 12 / 10 / 10 in the female and 12 / 12 / 08 and 12 / 12 / 10 in males, VENT 146-159, and SC 126-138; ratios SC / VENT 0.89-0.93 in males and 0.79 in the female; PRO and POO always 1 / 1 and 2 / 2, respectively; TEMP always 1 + 1; SL usually 9 (4-6) except for the left side of specimen USNM 342095, where it was 8 (3-5); IL 9 (1-6) / 9 (1-6) in males and 10 (1-5) / 10 (1-5) in the female. Coloration is coincident with literature descriptions (DIXON *et al.*, 1993). Related to Cerrado ecore-

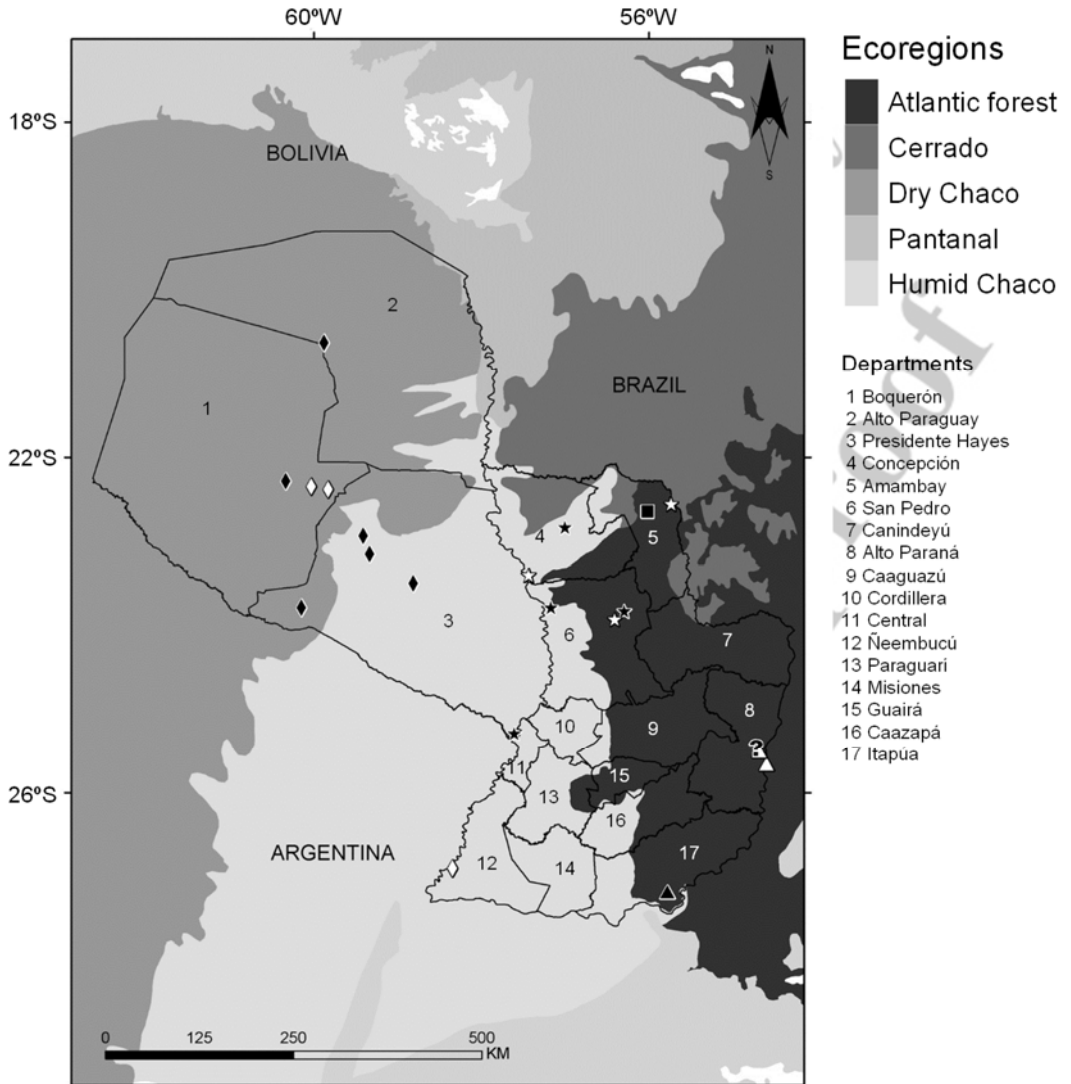


Figure 1: Political and ecoregional map of Paraguay, showing locality records of *Chironius bicarinatus* (triangles), *C. flavolineatus* (square), *C. maculoventris* (diamonds), and *C. quadricarinatus* (stars). White symbols represent literature records and black symbols represent specimens examined in the present study. The question mark represents the Alto Paraná record for *C. bicarinatus* and *C. exoletus*.

gion in the northeast area of Oriental Region of Paraguay (Amambay Department) (Fig. 1). This environment is dominated by natural grasslands with forests in island

patches or in gallery along streams.

Chironius maculoventris Dixon, Wiest & Cei, 1993. Three males and six females. DOR 12-13-14 / 12 / 10, VENT 143-161, and

SC 90-122; ratios SC / VENT 0.58-0.75 in males and 0.66-0.75 in females; PRO and POO always 1 / 1 and 2 / 2, respectively; TEMP usually 1 + 2, but sometimes 1 + 2 / 2 + 2 (CZ 512), 2 + 2 / 1 + 2 (MNHNP 3783), and 2 + 2 / 2 + 2 (MNHNP 3167, 9252); SL highly variable: 7 (4-5) / 7 (4-5) (MNHNP 9252), 7 (4-5) / 8 (4-5) (CZ 512), 8 (4-5) / 8(4-5) (MNHNP 3782, 5480), 8 (4-5) / 9 (5-6) (MNHNP 2504), 9 (5-6) / 8 (4-5) (MNHNP 10016), 9 (5-6) / 9 (5-6) (MNHNP 2505, 3167), and 9 (6-7) / 8 (4-5) (MNHNP 5226). IL 10 (1-6), except MNHNP 3782 -11 (1-6) / D-, MNHNP 5226 -8 (1-4) / 9 (1-5) -, and MNHNP 5480 -9 (1-6) / 9 (1-6) -. Coloration fits rather well with previous color descriptions (DIXON *et al.*, 1993) except for the brown color on the top of the head (olive color in literature). Black stripe on postocular and temporal areas reaches the neck. The iris is black. Our Paraguayan records are in Dry Chaco (Fig. 1), including bibliographic records from Loma Plata (DIXON *et al.*, 1993) and Filadelfia (ZIEGLER *et al.*, 2002), both in Boquerón Department. This ecoregion is composed by thorny vegetation (bromeliads, cactus) and the herbaceous stratus is almost absent. Nevertheless, some literature records also indicate its presence in Paraguayan and Argentinean Humid Chaco (GIRAUDO & CONTRERAS, 1994; GIRAUDO, 2001).

Chironius quadricarinatus (Boie, 1827). Three females and two males. DOR 12 / 12 / 10 and 14 / 12 / 10, but specimen MNHNP 10900 with 12 / 12 / 08; VENT 144 -154, and SC 91-129; ratios SC / VENT 0.89 in the only male for which it was calculated and 0.59-0.79 in the females; PRO and POO always 1 / 1 and 2 / 2, respectively; TEMP always 1 + 2; SL usually 9 (5-6), ex-

cept left side of MNHNP 10900, where it was 8 (4-5), and both sides of MNHNP 11699, where it was 8 (5-6); IL 10 (1-6), except MNHNP 5479, where it was 11 (1-7) / 11 (1-7); the IL of MNHNP 10900 was damaged. Head and neck reddish brown, and iris black; the rest of the coloration fits with the known parameters for the species (DIXON *et al.*, 1993). In Paraguay, this species is associated with Paraguay River Basin, in Humid Chaco ecoregion, reaching a patch of Cerrado in Laguna Blanca (San Pedro). Humid Chaco is seasonal flooding, with forests showing a mix of components between Dry Chaco and Atlantic Forests. The environment in Laguna Blanca resembles a Cerrado ecoregion habitat. DIXON *et al.* (1993) gave additional records for Carumbé (San Pedro Department), Concepción (Concepción Department), and Pedro Juan Caballero (Amambay Department), being the latter in Cerrado (Fig. 1).

DISCUSSION

Because the small sample size, it was not possible to test whether the differences in pholidosis ranges, according to sexual dimorphism, were significant. With these few samples, we observed that the ranges of ventral and subcaudal scales do not overlap between males and females of *C. flavolineatus* and *C. quadricarinatus* (Table 1). However, DIXON *et al.* (1993), who had a bigger sample size, recorded overlap among ventral scale numbers of those five species in both sexes, showing females of *C. flavolineatus* and *C. maculoventris* the same pholidosis range. Subcaudal scales showed no overlap between females of *C. bicarinatus* and *C. maculoventris*, and between males of *C. maculoventris* and those of

either *C. exoletus* or *C. flavolineatus* (DIXON *et al.* 1993).

Ventral scales of female *C. bicarinatus* showed the highest value for this pholidotic parameter, whereas males of *C. quadricarinatus* had the lowest, which coincides with the observations of DIXON *et al.* (1993). With respect to subcaudal scales, females of *C. bicarinatus* had the highest number among females, being this value even higher than that of males of *C. maculoventris* and *C. quadricarinatus*. This same pattern was also observed by DIXON *et al.* (1993). The male of *C. exoletus* had the highest number of subcaudal scales, with a value that was even higher than the number of ventral scales of male *C. flavolineatus* and *C. quadricarinatus*. DIXON *et al.* (1993) presented a range of subcaudal scales for *C. bicarinatus* males between 125 and 157, which were also the highest values recorded in that study. *Chironius maculoventris* and females of *C. quadricarinatus* had the lowest number of subcaudal scales, a similar pattern than that observed in the results of DIXON *et al.* (1993).

The difference between SC and VENT was highest in *C. maculoventris*, being rather small in males of the remaining species (ratios over 0.89). This motivated the absence of apparent sexual dimorphism in SC / VENT ratio in *C. maculoventris*. The SC / VENT ratio in both sexes of *C. maculoventris* was below 0.76, a range similar to that shown by females of the rest of species (Table 1).

MARQUES & SAZIMA (2003) stated that ontogenetic color changes are common for *Chironius*, arguing that even *C. flavolineatus* color changes ontogenetically, contrary to what DIXON *et al.* (1993) had claimed. Besides

ontogenetic color changes, the presence of a light vertebral stripe is rather consistent in hatchlings, juveniles or adults of *C. bicarinatus* and *C. flavolineatus* (DIXON *et al.*, 1993; CARREIRA & MANEYRO, 2013), and our observations confirmed that.

Coloration also has implications in phylogenetic structure. *Chironius maculoventris* and *C. quadricarinatus* are the most similar in dorsal color pattern, and they belong to sister clades, while *C. bicarinatus* and *C. flavolineatus* are nested in different clades (HOLLIS, 2006). DIXON *et al.* (1993) already stated that ventral coloration differs substantially between *C. quadricarinatus* and *C. maculoventris* (as subspecies of the nominal form). In addition to differences in coloration, we also observed some differences in ecoregional preferences that support the hypothesis proposed by HOLLIS (2006). In Paraguay, *C. maculoventris* has a strong affinity for the Dry Chaco (west of Paraguay River), whit some records in the Humid Chaco (GIRAUDO, 2001), whereas *C. quadricarinatus* is present in the Humid Chaco mainly near of the Paraguay River (CACCIALI *et al.*, 2014). In fact, according to current distribution data, all four species in Paraguay would be allopatric, except perhaps *C. bicarinatus* with *C. exoletus* (Fig. 1). However, in other countries, many species of the genus (even those present in Paraguay) live in sympatry (GIRAUDO, 2001; COLLI *et al.*, 2002; PINTO *et al.*, 2008), which makes us suppose that a more intense sampling effort could result in some observations of sympatry between *Chironius* species in Paraguay.

Chironius bicarinatus is the species that reaches the southernmost limit of the genus, being present in a variety of humid

environments: from northern Bahía along the Atlantic coast, to Rio Grande do Sul in the Atlantic Forest in Brazil; in areas that border forested environments along the Uruguay River and in Cerro Largo Department in Uruguay (CARREIRA & LOMBARDO, 2007; CARREIRA & MANEYRO, 2013); and acting as a common jungle dweller in Misiones (Argentina) (GIRAUDO, 2001), and also in Paraguay.

Chironius flavolineatus is a species inhabiting several different environments from dry habitats in Caatinga (RODRIGUES, 2003), palm savannas in Bolivia, to Cerrado (COLLI *et al.*, 2002). In Paraguay, this species was only recorded in the Cerrado.

Finally, some pholidosis aspects are out of the previously known range in *C. bicarinatus* and *C. maculoventris*, according to data from DIXON *et al.* (1993), GIRAUDO (2001), and CARREIRA & MANEYRO (2013). Namely, the new ventral pholidosis range for females of *C. bicarinatus* is 154-170, and for *C. maculoventris* is 143-157 for females and 154-161 for males. New subcaudal range have also been observed for males of *C. maculoventris* (90-125) and for females of *C. quadricarinatus* (91-123).

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