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## A new species of *Corydoras* Lacépède (Siluriformes: Callichthyidae) from the Rio Tapajós basin and its phylogenetic implications

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**ABSTRACT**

*A new species of* Corydoras *is described from tributaries of the rio Arinos, rio Teles Pires and rio Preto, all in the rio Tapajós basin. The new species is a member of a group that includes 36 species with spots on the body. Within this group, the new species can be readily distinguished by having a smaller dorsal-fin spine than the first three subsequent soft dorsal-fin rays; pectoral, pelvic and anal fins hyaline; dorsal-fin interradial membrane hyaline; rounded spots on trunk restricted to dorsolateral body plates and dorsal portion of ventrolateral body plates, not reaching the base of pelvic and anal fins. The new species can be further distinguished from* Corydoras xinguensis *by having spots with diffuse edges, and from all other species of spotted* Corydoras *except* C. multimaculatus, *by the absence of ventral platelets. A phylogenetic analysis recovered the new species plus* Corydoras metae *and* C. araguaiensis *in a clade sharing the presence of a pointed process on the maxilla for insertion of the* retractor tentaculi *muscle. In addition, the presence in the new species of an elongated anterior portion of the mesethmoid and a triangular uncinate process of the epibranchial 3 suggests a close relationship with* Corydoras metae.

Key-Words: Corydoradinae; Neotropical; Phylogeny; Taxonomy; Biodiversity.

## INTRODUCTION

*Corydoras* Lacépède is the most diversified catfish genus, currently including more than 160 valid species (Eschmeyer, 2013). The species of *Corydoras* are widely distributed throughout cis-Andean South America in habitats such as shallow marginal areas of rivers, pools, and smaller tributaries (Reis, 2003). Despite the huge diversity of shapes and color patterns among the species of *Corydoras,* the limits and definitions of a large amount of species are still unknown (Gosline, 1940; Nijssen & Isbrücker, 1980, 1986; Reis, 1998, 2003; Britto, 2003).

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Two species of *Corydoras* were originally described from the rio Tapajós basin: *C. bifasciatus* Nijssen 1972 and *C. ornatus* Nijssen & Isbrücker 1976. *Corydoras aeneus* (Gill, 1858) and *C. splendens* (Castelnau, 1855) were also recorded from the same basin (Britto *et al.,* 2007), and there are many other forms yet to be described (Fuller & Evers, 2005).

Nijssen (1970) proposed an assembly of *Corydoras* species, the "*C. punctatus*-group", grouping all species with spots scattered over the body, and divided into six subgroups according to the following features: (a) dark spot on the upper part of the dorsal fin; (b) dark mask across the eye; (c) long snout; (d) relatively elongate body; (e) deep body; and (f) relatively long dorsal-fin spine. The author also mentioned that the spotted *Corydoras* group has a large range of distribution, with records from the northern to central Neotropical region, and that it includes almost 35% of all described species. The present study will focus on specimens of the Nijssen's (1970) subgroups (a) and (e), plus *Corydoras araguaiensis* and *C. haraldschultzi.*

Recent material sampled from tributaries of rio Teles Pires, rio Arinos and rio Preto revealed a spotted *Corydoras,* somewhat resembling species like *C. albolineatus* Knaack, *C. maculifer* Nijssen & Isbrücker, *C. multimaculatus* Steindachner, *C. polystictus* Regan and *C. xinguensis* Nijssen. Examination of the material revealed that this is a new species of *Corydoras,* which is described herein.

## MATERIALS AND METHODS

Morphometric and meristic data were taken following Reis (1997), except for the length of the anal-fin spine, which is absent in all members of Corydoradinae. Length of the ossified portion of the pectoral-fin spine was measured from the point of articulation of the spine to the pectoral girdle to the distal tip of the spine (Reis, 1997). Measurements were taken with calipers to the nearest 0.1 mm. Teeth and vertebral counts were made from cleared-and-stained (cs) specimens prepared according to Taylor & Van Dyke (1985). Vertebral counts include 27-30 vertebrae, with the compound caudal central (preural 1 + ural 1) counted as a single element. Lateral plate counts include all dorsolateral and ventrolateral plates, except for the small, irregular plates on the caudal peduncle. Throughout the description, the numbers in parentheses following each count represent the total number of specimens with that value, and an asterisk indicates data for the holotype. Nomenclature of latero-sensory canals follows Schaefer & Aquino (2000), and that of preopercular pores follows Schaefer (1988). Osteological terminology follows Reis (1998), except that parieto-supraoccipital is used instead of supraoccipital (Arratia & Gayet, 1995), and compound pterotic instead of pterotic-supracleithrum (Aquino & Schaefer, 2002). Homology of barbels follows Britto & Lima (2003). Institutional abbreviations follow Sabaj Pérez (2010).

Phylogenetic analysis was performed using the morphological character data matrix exactly as published by Britto (2003) with the addition of the new taxon. The analysis was undertaken using T.N.T. software (Goloboff *et al.,* 2008) via a traditional heuristic search performed using the stepwise addition algorithm associated with tree bisection reconnection in a total of 10,000 samples. Attributes of connectivity and ambiguity among character-states were treated in the same way as in Britto (2003).

## RESULTS

### *Corydoras apiaka,* new species
### Fig. 1A, Fig. 1B, Table 1

*Holotype:* MNRJ 40720, 28.4 mm SL, Ribeirão Oito de Julho, a tributary of the right margin of rio Arinos, rio Tapajós Basin, at road MT-338 between Tapurah--Nova Paraná, Porto dos Gaúchos, Mato Grosso, 11°41'44"S, 57°06'42"W, 19 January 2002, P. Buckup, A. Aranda, F. Silva & C. Figueiredo.

*Paratypes:* BRAZIL, Mato Grosso, rio Tapajós basin: MNRJ 23358, 11 (+1 cs) 28.9-34.9 mm SL, collected with the holotype. MNRJ 23334, 1, 31.6 mm SL, Tapurah, rio São Venceslau on the Tapurah-Nova Paraná Road (MT-338), rio Arinos basin, 12°19'32"S, 56°40'31"W, 19 January 2002, P. Buckup, A. Aranda, F. Silva & C. Figueiredo. MNRJ 23657, 2, 33.7-34.6 mm SL, rio Arinos, Porto dos Gaúchos, 11°31'51"S, 57°25'08"W, 19 January 2002, P. Buckup, A. Aranda, F. Silva & C. Figueiredo. MZUSP 45340, 8, 30.8-39.5 mm SL, riacho Monjolinho, a tributary of rio Preto, Diamantino 14°20'00"S, 56°22'00"W, 24 October 1992, N. Menezes, H. Britski, O. Oyakawa & M. Triques. MZUSP 95885, 1, 34.05 mm SL, rio Teles Pires, Itaúba, 11°03'44"S, 55°19'08"W, 26 September 2007, J.L.O. Birindelli & P. Holanda Carvalho. MZUSP 99037, 1, 37.64 mm SL, rio Teles Pires basin unnamed stream at BR-163, Itaúba 11°06'51"S, 55°18'25"W, 18 February 2008, P. Holanda Carvalho & S. Lima.

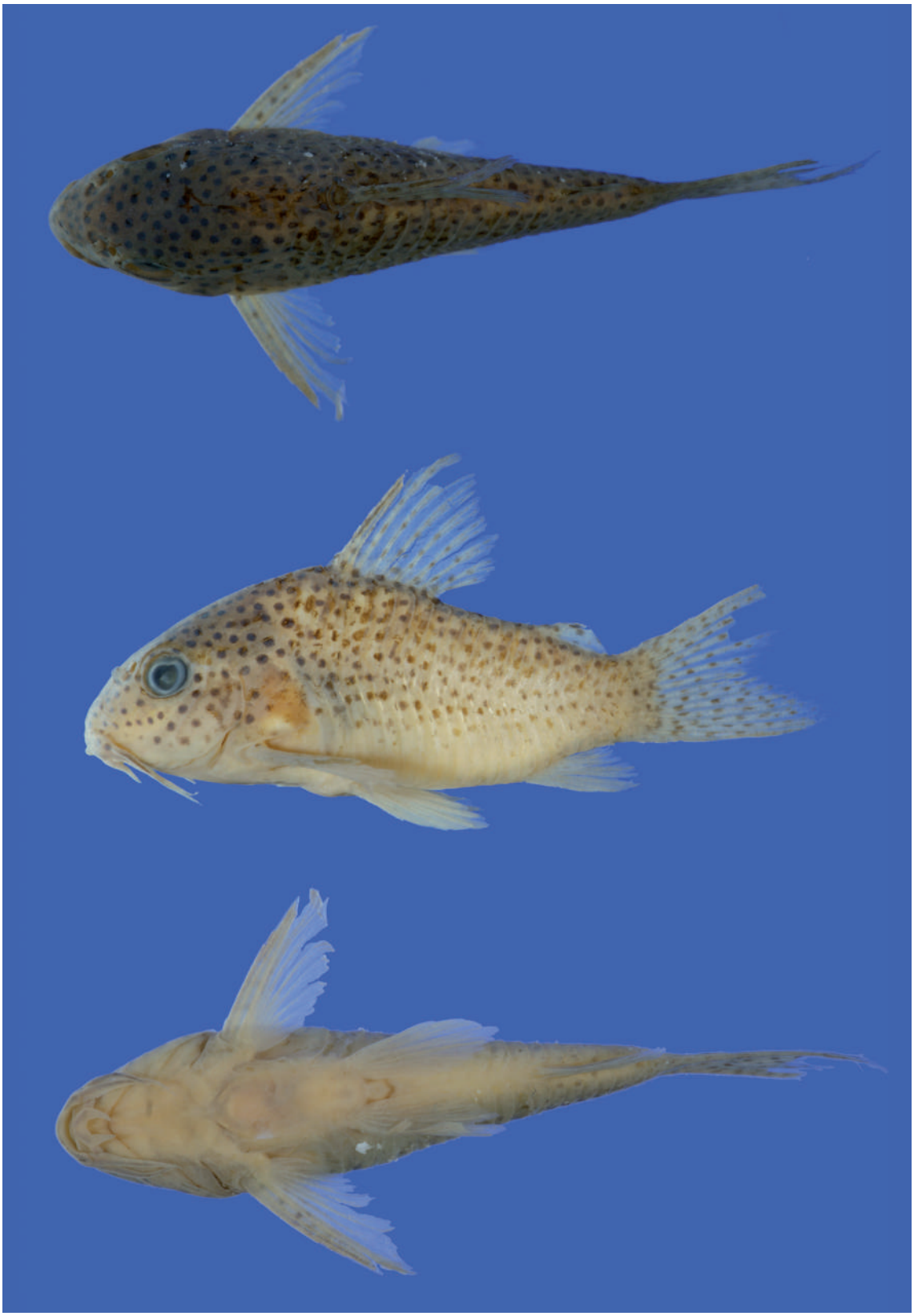

**FIGURA 1:** *Corydoras apiaka* MNRJ 40720, 28.4 mm, Ribeirão Oito de Julho, a tributary of the right margin of rio Arinos. Dorsal (upper), lateral (middle) and ventral (lower) views.

## Diagnosis

*Corydoras apiaka* differs from its spotted congeners by having the dorsal-fin spine smaller than the three anterior branched dorsal-fin rays (*vs.* dorsal-fin spine smaller than just two anterior dorsal-fin rays, or equal in size). *Corydoras apiaka* is distinguished from its congeners, except *C. albolineatus, C. araguaiaensis, C. haraldschultzi, C. julii, C. polystictus, C. multimaculatus* and *C. xinguensis* by the presence of numerous dark-brown spots over the head and body (*vs.* spots absent). *Corydoras apiaka* differs from *C. albolineatus, C. araguaiaensis* and *C. haraldschultzi* by having several spots scattered all over the head and trunk in a somewhat random pattern (*vs.* spots more concentrated and with a single pale horizontal stripe in the middle of the body in *C. albolineatus;* or spots arranged in three or more stripes along the trunk in *C. araguaiaensis* and *C. haraldschultzi*); pectoral, pelvic and anal fins hyaline (*vs.* several series of small blotches over fin rays), and adipose fin hyaline or bearing one spot (*vs.* two or more spots). The new species can be further distinguished from *C. multimaculatus* and *C. xinguensis* by blotches on interradial membrane of dorsal fin absent (*vs.* present); adipose fin hyaline or with a single spot (*vs.* two or three well defined spots); spots not reaching over the anal fin base (*vs.* spots extending to anal-fin base). *Corydoras apiaka* is distinguished from *C. xinguensis* by spots on anal fin absent (*vs.* present); body spots with diffuse border (*vs.* spots with well delimited edge). *Corydoras apiaka* further differs from all other spotted species, with the exception of *C. multimaculatus,* by the naked ventral region (*vs.* belly with small platelets).

**TABLE 1:** Morphometric data for *Corydoras apiaka.*

| | Holotype | Paratypes (n=23) | | SD |
|---|---|---|---|---|
| | MNRJ | Range | Mean | |
| Standard length (mm) | 28.4 | 28.9-38.8 | 32.3 | 2,68 |
| Head length (mm) | 13.1 | 10.4-13.3 | 11.8 | 1,53 |
| **Percentages of standard length** | | | | |
| Depth of body | 39.5 | 36.9-42.6 | 39.9 | 1,48 |
| Predorsal distance | 50.9 | 48.1-53.9 | 51.3 | 1,87 |
| Prepelvic distance | 45.4 | 43.5-51.7 | 47.1 | 2,90 |
| Preanal distance | 75.7 | 68.8-81.5 | 78.2 | 2,59 |
| Preadipose distance | 79.3 | 75.5-85.2 | 80.3 | 1,95 |
| Length of dorsal spine | 21.3 | 16.1-24.6 | 20.2 | 1,88 |
| Length of pectoral spine | 28.8 | 21.9-28.6 | 24.8 | 1,36 |
| Length of adipose-fin spine | 8.1 | 5.7-11.0 | 8.6 | 1,02 |
| Depth of caudal peduncle | 15.2 | 13.4-17.1 | 15.2 | 9,24 |
| Dorsal to adipose distance | 37.2 | 16.6-39.2 | 29.4 | 1,33 |
| Length of dorsal-fin base | 21.0 | 17.3-22.5 | 19.55 | 7,62 |
| Maximum cleithral width | 26.5 | 8.9-29.9 | 21.3 | 3,83 |
| Head length | 46.0 | 31.1-46.2 | 42.7 | 2,21 |
| Length of longer barbel | 19.4 | 12.1-20.9 | 17.0 | 4,88 |
| Percentage of head length | | | | |
| Head depth | 36.9 | 28.4-41.4 | 36.5 | 5,82 |
| Least interorbital distance | 14.4 | 13.8-17.3 | 15.5 | 3,50 |
| Horizontal orbit diameter | 6.2 | 5.3-9.1 | 7.5 | 7,70 |
| Snout length | 8.7 | 7.2-16.6 | 10.7 | 3,37 |
| Least internareal distance | 7.2 | 6.7-10.5 | 8.3 | 2,68 |

*Description:* Morphometric data presented in Table 1. Head compressed with slight convex dorsal profile

**FIGURA 2:** *Corydoras apiaka* MZUSP 95885, 34.05 mm SL, rio Teles Pires. Living specimen, lateral view.

(Fig. 1); roughly triangular in dorsal view. Snout rounded. Head profile convex from upper lip to tip of parieto-supraoccipital expansion. Dorsal profile of body slightly convex from tip of parieto-supraoccipital expansion to base of last dorsal-fin ray. Body slightly concave from last ray of dorsal fin to base of adipose-fin spine; straight to slightly concave from that point to caudal-fin base. Ventral profile of body straight from isthmus to pelvic-fin origin, slightly convex from that point to anal-fin origin. Profile slightly concave from first anal-fin ray to caudal-fin base. Body roughly triangular in cross section at pectoral girdle, gradually becoming more compressed toward caudal fin.

Eye round, dorsolateral on head; orbit delimited dorsally by frontal and sphenotic, ventrally by infraorbitals. Anterior and posterior nares close to each other and only separated by flap of skin. Anterior naris tubular. Posterior naris close to anterodorsal margin of orbit, separated from orbit by distance slightly smaller than naris diameter. Mouth small, subterminal, width nearly equal to bony orbit diameter. Maxillary barbel not reaching anteroventral limit of gill opening. Length of maxillary barbel nearly equal to that of outer mental barbel. Inner mental barbel fleshy. Small rounded papillae covering entire surface of all barbels, upper and lower lips, and isthmus. Gill membranes united to isthmus. Four branchiostegal rays covered by thin layer of skin; two distal branchiostegal rays united at their tips by branchiostegal cartilage. Teeth on upper pharyngeal tooth plate 46(1), and on fifth ceratobranchial 45(1).

Posterior area of mesethmoid, frontal, sphenotic, compound pterotic, and parieto-supraoccipital visible externally, all covered by thin layer of skin and bearing minute scattered odontodes. Frontal fontanel elongate, ellipsoid, covered by thin layer of skin; posterior portion extending into parieto-supraoccipital. Nasal slender, curved laterally, mesial border contacting frontal. Frontal rectangular; anterior expansion in contact with nasal bone, posterior portion contacting sphenotic and parieto-supraoccipital. Sphenotic trapezoid in shape, contacting parieto-supraoccipital dorsally, compound pterotic posteriorly, second infraorbital ventrally. Compound pterotic roughly pipe-shaped, with posterior expansion contacting first lateral-line ossicle. Ventral margin of compound pterotic contacting opercle and cleithrum. Parieto-supraoccipital quadrangular with posterior expansion notched at its tip, sutured with nuchal plate.

Two infraorbital bones, externally visible, covered by thin layer of skin. First infraorbital with anterior expansion. Second infraorbital bone contacting only sphenotic posteriorly. Opercle exposed, slender in shape, with smooth free border. Preopercle externally visible, slender and covered by thin layer of skin.

Trunk lateral line with three laterosensory canals; two anteriormost canals reduced to small ossicles. Last lateral-line canal encased in second dorsolateral body plate. Lateral-line canal entering neurocranium through compound pterotic, splitting into three branches before entering sphenotic: pterotic and preoperculomandibular, each with single pore. Sensory canal continuing through compound pterotic, entering sphenotic as temporal canal, which splits into two branches: one branch giving rise to infraorbital canal, the other branch entering frontal through supraorbital canal. Supraorbital canal not branched, running through nasal bone. Epiphyseal pore opening at supraorbital main canal. Nasal canal with single opening at each end. Infraorbital canal running through entire second infraorbital, extending to infraorbital 1 and opening into three pores. Preoperculomandibular branch giving rise to preoperculomandibular canal, which runs through entire preopercle with three openings, leading to pores 3, 4, and 5, respectively.

Body plates with minute odontodes restricted to posterior margins. Nuchal plate exposed. Posterior tip of cleithrum along vertical through dorsal-fin spinelet. Cleithrum and mesial process of scapulocoracoid exposed. Body plates not touching counterparts ventrally, leaving narrow naked area. Dorsolateral body plates 23(2), 24*(24); ventrolateral body plates 21*(25), 22(1); dorsolateral body plates along dorsal-fin base 6(7), 7*(19); dorsolateral body plates from adipose fin to caudal-fin base 8*(23), 9(3); preadipose platelets 3(1), 4(3), 5*(18), 6(4). Precaudal vertebrae 10, and caudal vertebrae 11. Six pairs of ribs, first pair conspicuously larger than others.

Dorsal fin roughly triangular, located just posterior to second dorsolateral body plate. Dorsal-fin spine shorter than first branched ray. Anterior border of dorsal-fin spine smooth; posterior border with 3-18 minute serrations (26). Dorsal-fin rays II,8* (26). Adipose fin roughly triangular, separated from base of last dorsal-fin ray by 7-8* dorsolateral body plates. Anal fin roughly triangular, located just posterior to 13th ventrolateral body plates, and at vertical through anterior margin of adipose-fin spine. Anal-fin rays ii,5,i (26). Pectoral fin triangular, its origin located just posterior to gill opening. Ossified portion of pectoral-fin spine shorter than first branched ray. Distal tip of spine with minute, segmented, unossified portion. Pectoral-fin spine with 16-25 small serrations along entire posterior border. Pectoral serrations more developed than those of dorsal spine. Pectoral-fin rays

I,8*(22), or I,7(4). Pelvic fin ellipsoid, located just below first ventrolateral body plate, and at vertical through first branched dorsal-fin ray. Pelvic-fin rays i,5*(26). Caudal fin forked; upper lobe slightly longer. Principal caudal-fin rays i,6/6,i(26). Upper and lower procurrent caudal-fin rays both 5(26). All fins with minute odontodes scattered over all rays.

*Color in alcohol:* Ground coloration of head light brown to brown, light brown ventrally. Interorbital to supraoccipital region darker than snout, anterior and posterior margins of the eye to opercle. Several small irregular chromatophores scattered over snout to parieto-supraoccipital. Chromatophores less concentrated over lower anterior and posterior margins on opercle and superior surfaces. Mental barbels dark brown, remaining barbels yellowish light brown.

Ground color of trunk yellowish white to light brown. Brownish white on dorsal surface near dorsal fin. Small white area on cleithrum surface. Long dark brown stripe from compound pterotic to pectoral fin posterior tip line. Small irregular chromatophores scattered over dorsolateral plates to upper portions of ventrolateral plates. Lower portions of ventrolateral plates yellowish brown. In smaller specimens, small irregular chromatophores over lower portions of ventrolateral plates. Scattered irregular chromatophores on dorsal spine, dorsal-fin rays, preadipose platelets, adipose-fin spine and membrane, and caudal-fin rays. Pectoral, pelvic and anal fins hyaline.

*Phylogenetic relationships:* Insertion of the new species in Britto's (2003) data matrix, recovered the following clade: (*Corydoras araguaiensis* (*Corydoras metae* + *Corydoras apiaka*)). The monophyletic clade including *Corydoras apiaka* and *C. metae* is supported by two synapomorphies: anterior portion of mesethmoid long and uncinate process of epibranchial 3 triangular. The monophyletic clade including *Corydoras araguaiensis* (*C. metae* + *C. apiaka*) is supported by just one synapomorphy: pointed process on the maxilla for insertion of the *retractor tentaculi* muscle. Also, the new species shows the following homoplastic features: process on anterolateral margin of frontal bone (also present in *Corydoras britskii, C. rabauti, C. aeneus, C. pygmaeus, C. vittatus, C. septentrionalis, C. stenocephalus, C. gracilis, C. ephippifer, C. julii, C. difluviatilis, C. flaveolus, C. arcuatus, C. habrosus, C. axelrodi, C. cochui, C. nattereri, C. aurofrenatus,* and *C. loretoensis*), complex vertebra slender (also including *Corydoras vittatus, C. acutus, C. ellisae, C. stenocephalus, Corydoras difluviatilis, C. undulatus, C. gracilis, C. osteocarus, C. garbei, C. ornatus, C. paleatus*), a fully interdigitated junction between metapterygoid and hyomandibular (including *Corydoras zygatus, C. acutus, C. ellisae, C. stenocephalus, C. undulatus, C. gracilis, C. nanus, C. napoensis, C. elegans, C. bicolor, C. trilineatus, C. osteocarus, C. julii, C. araguaiensis, C. flaveolus, C. arcuatus, C. baderi, C. habrosus* and *C. cochui*) and dorsal lamina on anguloarticular triangular (present in *Corydoras reticulatus, C. difluviatilis, C. ornatus,* and *C. agassizi*).

*Sexual dimorphism:* No sexually dimorphic characters found. Corydoradine catfishes often have dimorphic genital papillae (see Britto, 2003), but specimens of *Corydoras apiaka* have no pectoral-fin spine serration modifications.

*Distribution: Corydoras apiaka* is only known from tributaries of the rio Arinos, rio Teles Pires and rio Preto, clearwater tributaries of the upper rio Tapajós in Mato Grosso State, Brazil (Figs. 3, 4).

*Habitat and ecological notes: Corydoras apiaka* was mostly found in lotic habitats in the rio Arinos and its tributaries. The rio Arinos has a muddy-brown color, with soft bottom of clay and sand. Most of the specimens were captured in the small forest streams of black or clear water, or in marginal ponds.

*Etymology:* The specific name *apiaka* is treated as a noun in apposition and is named for the indigenous tribe Apiaká (means "people" in Tupi language), which originally occupied the middle and lower rio Arinos, lower rio Juruena, but is nowadays restricted to the lower rio Juruena (Menéndez, 1992). The tribe is known for facial tattoos and bravery in battles, as well as by anthropophagic rites after fights (Castelnau, 1850).

## DISCUSSION

All evidence assigns the non-monophyly of a spotted group of *Corydoras.* A recent published study about mimetic lineages in *Corydoras* performed by Alexandrou *et al.* (2011) shows relationships and patterns among co-mimics of certain regions. The authors pointed out that those sympatric co-mimics are more similar in coloration than those in allopatry. The test suggested a highly significant relationship between color pattern and geographical distribution. The authors identified 52 species belonging to 24 different mimicry rings, combining phylogenetic analysis and geographic distribution, each composed

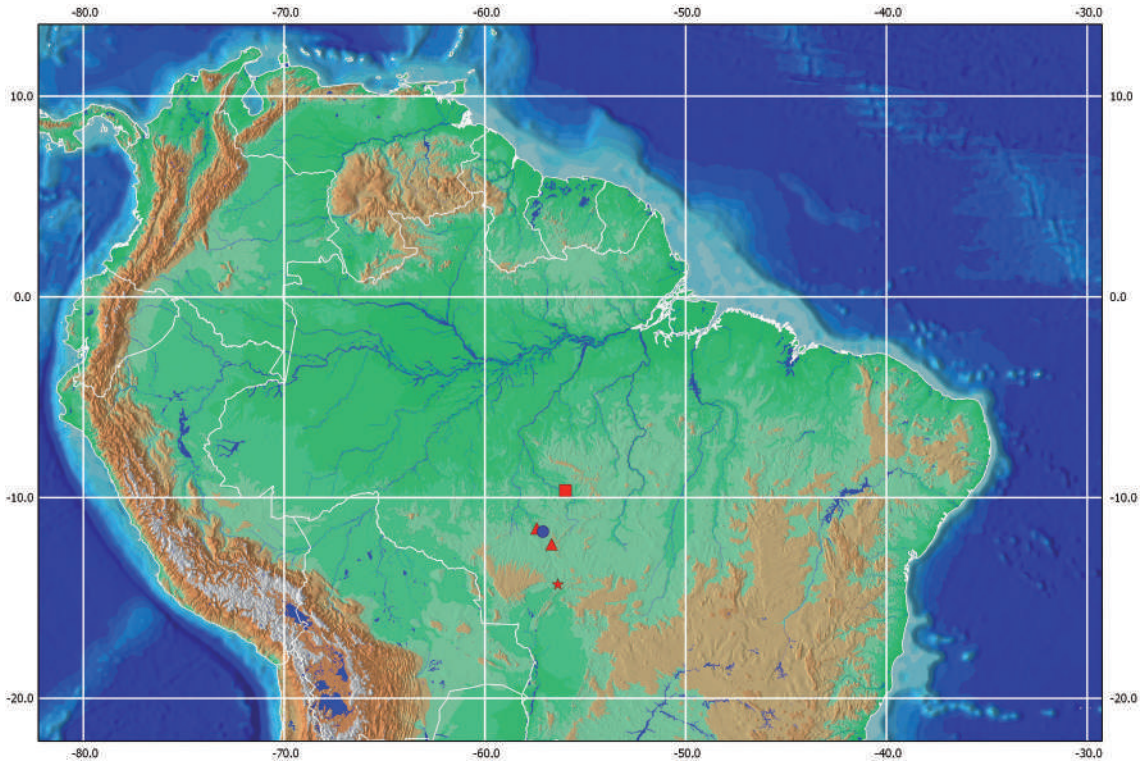


**FIGURA 3:** Map of northern South America showing the distribution of *Corydoras apiaka* (circle) holotype; rio Arinos (triangles); rio Teles Pires (squares); rio Preto (star).

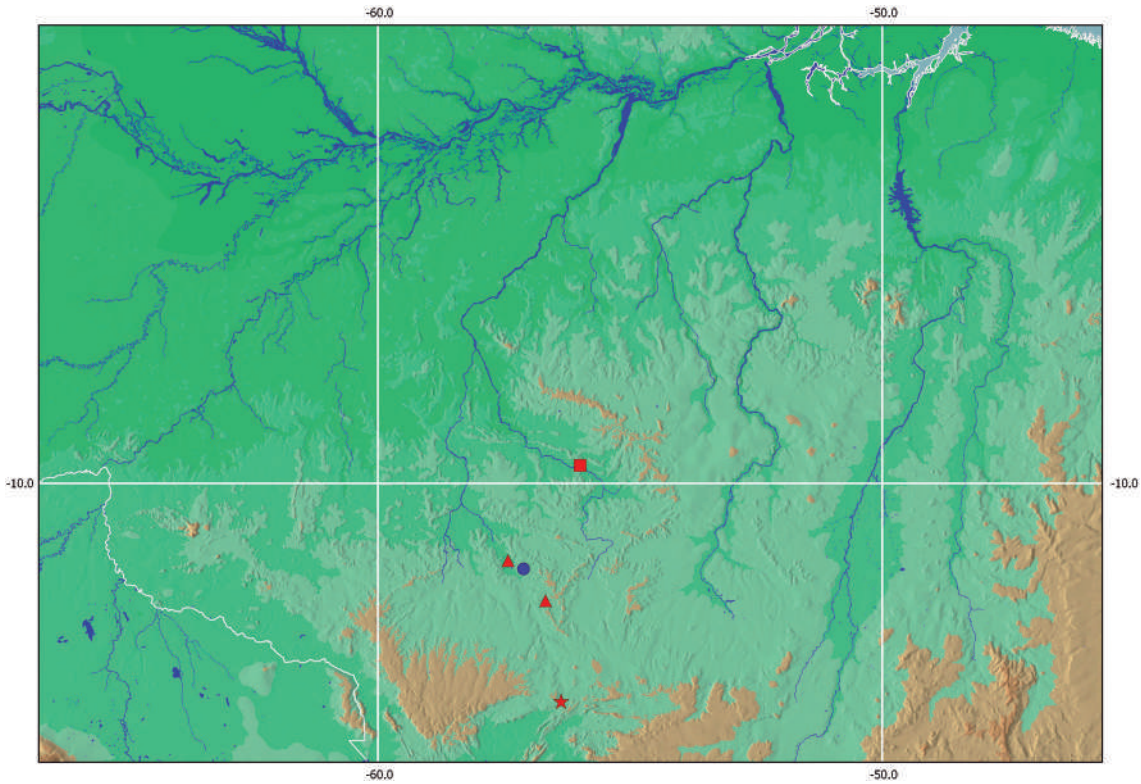


**FIGURA 4:** Detail of distribution of *Corydoras apiaka* shown in Fig. 2. (circle) holotype; rio Arinos (triangles); rio Teles Pires (squares); rio Preto (star).

of two or three species. The co-mimic rings are composed of different evolutionary lineages corroborating Britto's (2003) hypothesis that color pattern is convergent and recovers weak phylogenetic signal. The new species, *Corydoras apiaka* (not included in the analysis) is the only described spotted *Corydoras* from Tapajós basin; another three described species from same basin (*C. aeneus, C. bifasciatus* and *C. ornatus*) have no spotted pattern. Yet many *Corydoras* morphotypes are still undescribed and demand taxonomic review (*e.g.,* Fuller & Evers, 2005:280-361).

We agree with Britto's (2003) and Alexandrou *et al.* (2011) hypothesis that go against Nijssen's (1970) division of *Corydoras* into eight groups, one of them being the "*punctatus*-group" represented by the spotted *Corydoras.* The highly homoplastic spotted color patterns serve as evidence for the complexity of the evolution in the genus.

*Comparative material:* Listed in Britto & Lima (2003) and Britto (2003) with the addition of: *Corydoras albolineatus* MNRJ 33864 (5); *Corydoras araguaiensis* MNRJ 25495 (2); MNRJ 24937 (2); MZUSP 86269 (67, 1 cs); *Corydoras cervinus* MNRJ 33867 (1); *Corydoras xinguensis* MZUSP 38980 (1), paratype; MNRJ 24871 (1); MZUSP 38974 (1) paratype; MZUSP 87047 (15); MZUSP 87098 (1); *Corydoras haraldschultzi* MZUSP 94996 (299); *Corydoras julii* MNRJ 33869 (36); MNRJ 33870 (3); *Corydoras multimaculatus* MNRJ 16118 (6); *Corydoras polystictus* MNRJ 12418 (9).

## RESUMO

*Uma nova espécie de* Corydoras *é descrita dos tributários dos rios Arinos, Teles Pires e Preto, bacia do rio Tapajós. A nova espécie é membro de um grupo com pontilhados no corpo que inclui 36 espécies. Dentro desse grupo, a nova espécie pode ser facilmente distinguida pelo espinho dorsal menor que os três primeiros raios ramificados da nadadeira dorsal; nadadeiras peitorais, pélvicas e anal hialinas; membranas inter-radiais da nadadeira dorsal hialina; presença de pontilhados redondos no tronco restritas as placas dorsolaterais do corpo e porções dorsais das placas ventrolaterais não alcançando a base das nadadeiras pélvicas e anal. A nova espécie pode ser distinguida de* Corydoras xinguensis *por pontilhados com margens difusas e das demais espécies de* Corydoras *com pontilhado, exceto em* C. multimaculatus, *pela ausência de pequenas placas ventrais. Uma análise filogenética recuperou a nova espécie mais* Corydoras metae *e* C. araguaiensis *em um agrupamento compartilhando a presença de um processo pontiagudo para inserção do músculo* retractor tentaculi *no maxilar. A porção anterior do mesetmóide alongada e o processo uncinado do epibranquial 3 triangular indicam uma relação mais próxima com* Corydoras metae.

PALAVRAS-CHAVE: Corydoradinae; Neotropical; Filogenia; Taxonomia; Biodiversidade.

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