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A new species of *Harttia* from the rio São Francisco basin (Siluriformes: Loricariidae)

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The genus *Harttia* belongs to the subfamily Loricariinae and has to date 27 described species, distributed in the drainages of Guiana Shield, Amazon and southeastern Brazil. The new species is distinguished from its congeners by the combination of: canal plate present; abdominal plates absent; trapezoid preanal plates; males with elongated and conspicuous odontodes on the first pectoral-fin ray and on the lateral region of the head, close to the canal plate; and dorsal-fin spinelet present. An identification key for the species of the rio São Francisco basin and a comparison between the new taxon and all other species of the genus are presented.

Keywords: Brazilian Crystalline Shield, Brazilian Plateau, Identification key, Streams, Waterfalls.

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O gênero *Harttia* pertence à subfamília Loricariinae e possui 27 espécies descritas, distribuídas nas drenagens do Escudo das Guianas, Amazônica e do sudeste brasileiro. A nova espécie distingue-se das congêneres pela combinação de: placa do canal presente; placas abdominais ausentes; placas pré-anais trapezóides; machos com odontódeos alongados e conspícuos no primeiro raio da nadadeira peitoral e na região lateral da cabeça, próximo a placa do canal; e spinelet da nadadeira dorsal presente. Apresenta-se uma chave de identificação para as espécies da bacia do rio São Francisco e a comparação com todas as demais espécies do gênero.

Palavras-chave: Cachoeiras, Chave de identificação, Escudo Cristalino Brasileiro, Planalto Brasileiro, Riachos.

INTRODUCTION

The genus *Harttia* Steindachner, 1877 belongs to the subfamily Loricariinae, comprising 27 species (Fricke *et al*., 2022; Tab. 1), that inhabit the upper portions of medium and large rivers, with rocky or sandy bottoms, in the drainages of the rivers Doce, Jequitinhonha, Paraíba do Sul, Paraná, Ribeira de Iguape, São Francisco, Orinoco, rivers of Guiana Shield, and Amazon (Covain *et al*., 2012; Oyakawa *et al*., 2018). Rapp Py-Daniel (1997) diagnosed the genus as monophyletic by having: anterior internal process of the basipterygium oriented mesially and not connected to the contralateral element medially, bifurcation point of the infraorbital and supraorbital canals between the sphenotic and the compound pterotic, first ceratobranchial with a wide flap, parapophysis of the fourth vertebra not connected to the transcapular ligament, terminal exit of the parietal branch in the supraoccipital. Other authors have diagnosed the genus *Harttia* by having an elongated and flattened body, lateral keel of the body absent; large bony plates surrounding the anal papilla, and caudal fin emarginated (Oyakawa, 1993; Rapp Py-Daniel, Oliveira, 2001; Rapp Py-Daniel, Ohara, 2013).

More recently, Londoño-Burbano, Reis (2021) in a combined molecular and morphological phylogeny of the Loricariinae tested all the synapomorphies proposed by Rapp Py-Daniel (1997), and only one, the point of bifurcation of the infraorbital and supraorbital canals on the sphenotic (their character 37) resulted as a non-exclusive synapomorphy of *Harttia*, which was confirmed as monophyletic, corroborating Rapp Py-Daniel (1997), Provenzano (2011), and Covain *et al*. (2016). Londoño-Burbano, Reis (2021) also differentiate *Harttia* from other Loricariini by a combination of plates on caudal peduncle smooth, without keels; odontodes usually not well developed on sides of head or predorsal region; canal-bearing cheek plate with short, broad ventral process; caudal peduncle strongly depressed (*vs*. plates on caudal peduncle keeled, not smooth; odontodes well developed on sides of head or predorsal region; canal-bearing cheek plate with long and thin ventral process; caudal peduncle oval in cross-section in *Harttiella* Boeseman, 1971) and dark blotch at caudal-fin base; tip of snout naked, devoid of plates; abdominal plates absent or present as small platelets, partially or completely covering the abdomen (*vs*. dark transverse, half-moon shaped band at caudal-fin base, occupying the base of all rays of upper and lower lobes; tip of snout covered with plates;

abdominal plates, as medium-sized polygonal plates completely covering the abdomen in *Cteniloricaria* Isbrücker & Nijssen, 1979).

Oyakawa *et al*. (2018) divided the genus into three groups based on the coverage of plates in the abdominal region: 1) *Harttia loricariformis* group, whose members have a naked abdomen (without plates); 2) *H. rhombocephala* group, with abdomen partially covered by plates; and 3) *H. fowleri* group, with fully plated abdomen (for more information on the species composition of each group see Tab. 1).

To date, the rio São Francisco basin has the greatest diversity of the genus in southeastern Brazil, housing four species: *Harttia leiopleura* Oyakawa, 1993, *H. longipinna* Langeani, Oyakawa & Montoya-Burgos, 2001, *H. novalimensis* Oyakawa, 1993, and *H. torrenticola* Oyakawa, 1993. Our analyses indicate the occurrence of a new species from the Serra da Canastra National Park region, already mentioned in the literature as *Harttia* sp. (Casatti, Castro, 1998), *Harttia* cf. *novalimensis* (Romero, Casatti, 2012; Roa-Fuentes *et al*., 2015), and *H. novalimensis* (Angulo, 2019). The description of the new species, its comparison with all other species of the genus and an identification key for the species in the basin are presented here.

TABLE 1 | Currently recognized species of *Harttia* presented in three groups based on abdominal covering according to Oyakawa *et al.* (2018) and their type locality.

Species	Type locality
Without abdominal plates	
Harttia canastra	Rio São Francisco, São Francisco basin, São Roque de Minas municipality, southeastern Brazil
Harttia carvalhoi Miranda-Ribeiro, 1939	Rio Paquequer, Paraíba do Sul basin, southeastern Brazil
Harttia depressa Rapp Py-Daniel & Oliveira, 2001	Rio Pitinga, rio Uatumã basin, below the Paranapanema Enterprise dam, Cachoeira 40 Ilhas, left bank of the rio Amazonas, Amazonas basin
Harttia garavelloi Oyakawa, 1993	Rio Fanado, Jequitinhonha basin, southeastern Brazil
Harttia gracilis Oyakawa, 1993	Tributary of the rio São João, rio Grande, upper Paraná basin, southeastern Brazil
Harttia guianensis Rapp Py-Daniel & Oliveira, 2001	Rio Approuague, Saut Athanase, Approuague basin, French Guiana
Harttia intermontana Oliveira & Oyakawa, 2019	Córrego Bananeiras, tributary of the rio Gualaxo do Norte, Doce basin, Ouro Preto municipality, southeastern Brazil
Harttia kronei Miranda-Ribeiro, 1908	Rio Betari, Ribeira de Iguape basin, southeastern Brazil
Harttia leiopleura Oyakawa, 1993	Tributary of the Mutuca stream, rio das Velhas, São Francisco basin, southeastern Brazil
Harttia loricariformis Steindachner, 1877	Rio Paraíba do Sul, Paraíba do Sul basin, southeastern Brazil
Harttia merevari Provenzano, Machado-Allison, Chernoff, Willink & Petry, 2005	Rio Caurá, at the top of Salto Pará waterfalls, among rocks on the eastern side of the river, Orinoco basin, Bolívar State, Venezuela
Harttia novalimensis Oyakawa, 1993	Tributary of the Mutuca stream, rio das Velhas, São Francisco basin, southeastern Brazil
Harttia torrenticola Oyakawa, 1993	Tributary of the rio Paraopeba, São Francisco basin, southeastern Brazil
Harttia uatumensis Rapp Py-Daniel & Oliveira, 2001	Rio Uatumã, at Santa Luiza, Uatumã basin, left bank of the rio Amazonas, Amazonas basin

TABLE 1 | (Continued)

Species	Type locality
Abdomen partially covered by plates	
Harttia fluminensis Covain & Fisch-Muller, 2012	Rio Coppename, at Raleighvallen, Coppename basin, Suriname
Harttia longipinna Langeani, Oyakawa & Montoya-Burgos, 2001	Rio Pará, bridge on road BR 262 between Nova Serrana and Pará de Minas, São Francisco basin, southeastern Brazil
Harttia punctata Rapp Py-Daniel & Oliveira, 2001	Rio Tocantins, on rocks just below the Tucurui dam, Tocantins-Araguaia basin
Harttia rhombocephala Miranda-Ribeiro, 1939	Rio Farias, coastal basin, southeastern Brazil
Harttia rondoni Oyakawa, Fichberg & Rapp Py-Daniel, 2018	Rio Curuá, tributary of the rio Iriri, near Castelo dos Sonhos, Novo Progresso municipality, Rio Xingu basin, left bank of the rio Amazonas, Amazonas basin
Harttia trombetensis Rapp Py-Daniel & Oliveira, 2001	Rio Trombetas, Cachoeira Vira-Mundo, Trombetas basin, left bank of the rio Amazonas, Amazonas basin
Harttia tuna Covain & Fisch-Muller, 2012	Sipaliwini Savannah in Trio Amerindian territory at the Suriname-Brazil border, Four Brothers Mountains in a tributary of the rio Paru de Oeste, gift of the Trio tribe in Sipaliwini, Trombetas basin, left bank of the rio Amazonas, Amazonas basin
Abdomen completely covered by plates	
Harttia absaberi Oyakawa, Fichberg & Langeani, 2013	Ribeirão São Mateus, tributary of the rio Sucuriú, rio Paraná, upper Paraná basin, southeastern Brazil
Harttia dissidens Rapp Py-Daniel & Oliveira, 2001	Rio Tapajós, Pimental, Tapajós basin, right bank of the rio Amazonas, Amazonas basin
Harttia duriventris Rapp Py-Daniel & Oliveira, 2001	Rio Tocantins, Igarapé Bacuri, Tocantins-Araguaia basin
Harttia fowleri Pellegrin, 1908	Rio Camopi, Oyapock basin, French Guiana
Harttia panara Oyakawa, Fichberg & Rapp Py-Daniel, 2018	Rio Curuá, tributary of the rio Iriri, above the Cachoeira do Curuá waterfall, on the bridge at highway Cuiabá-Santarém (BR-163), Novo Progresso municipality, Rio Xingu basin, left bank of the rio Amazonas, Amazonas basin
Harttia surinamensis Boeseman, 1971	Gran Rio, upper Suriname basin, Suriname
Harttia villasboas Oyakawa, Fichberg & Rapp Py-Daniel, 2018	Rio Curuá, tributary of the rio Iriri, above two waterfalls, near the Churrascaria Cachoeira do Curuá at highway Cuiabá-Santarém (BR-163), Novo Progresso municipality, Rio Xingu basin, left bank of the rio Amazonas, Amazonas basin

MATERIAL AND METHODS

Measurements and counts, taken under a stereomicroscope, follow Oyakawa *et al.* (2018). The morphometric data were taken with a digital caliper, from point-to-point, approximation of 0.1 mm, and on the left side of the specimens; central tendency measures, such as minimum and maximum values, mean (for measurements), mode (for counts) and standard deviation were calculated in Microsoft Excel 2010 software. The standard length (SL) is expressed in millimeters, the other measurements are presented as a percentage of the standard length (measurements referring to the body, except head parts) or head length (HL; measurements referring to the head); the numbers in parentheses refer to the mean or the mode. The nomenclature and the counting of the body plates follow Schaefer (1997). According to Oyakawa *et al.* (2018) and Oliveira, Oyakawa (2019), the abdomen comprises the area between the pectoral girdle, the lateral thoracic plates and the pre-anal plates, or the urogenital pore, in case the pre-anal plates

are lacking. The list of the examined material includes the acronym of the collection and the catalog number, followed by the number of copies in alcohol and, in parentheses, the specimens cleared and stained (c&s) according to Taylor, Van Dyke (1985). Non-types are small or dissected specimens, not used for taking measures and counts.

Data referring to *Harttia depressa* Rapp Py-Daniel & Oliveira, 2001, *H. fluminensis* Covain & Fisch-Muller, 2012, *H. merevari* Provenzano, Machado-Allison, Chernoff, Willink & Petry, 2005, *H. rhombocephala* Miranda Ribeiro, 1939, and *H. tuna* Covain & Fisch-Muller, 2012 were taken from the original descriptions. In the identification key, some data are from Oyakawa (1993) and Langeani *et al*. (2001).

The material examined comes from the fish collections of the Departamento de Ciências Biológicas, Universidade Estadual Paulista "Júlio de Mesquita Filho", São José do Rio Preto (DZSJRP); Instituto Nacional de Pesquisas da Amazônia, Manaus (INPA); Laboratório de Ictiologia da Universidade de São Paulo, Ribeirão Preto (LIRP); Museu de Ciências Naturais, Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte (MCNIP); Museu de Ciências e Tecnologia, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre (MCP); Museum d'Histoire Naturelle, Département d'Herpétologie et Ichthyologie, Ville de Genève, Genève (MHNG); Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro (MNRJ); and Museu de Zoologia da Universidade de São Paulo, São Paulo (MZUSP).

RESULTS

Harttia canastra, new species

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(Figs. 1–4; Tab. 2)

Harttia sp. —Casatti, Castro, 1998:232, 233, 236 [tabs. 1–2; fig. 3m, paratype, male; 5 ecology, spatial distribution, behavior, figure]. —Casatti, Castro, 2006:204, 206, 210–211 (tabs. 1–2; figs. 2–3, 8, ecomorphology).

Harttia cf. *novalimensis*. —Romero, Casatti, 2012:541 [ecology]. —Roa-Fuentes *et al*., 2015:170, 178 [ecomorphology, feeding behavior, list].

Harttia novalimensis (not Oyakawa). —Angulo, 2019:208 [brain comparative anatomy].

Harttia sp. São Roque. —Cherobim, 2022:282 (morphological phylogenetic relationships), 307 (appendix 1, material examined).

Harttia sp. São Francisco. —Cherobim, 2022:344 (in table), 356 (molecular phylogenetic relationships).

Holotype. LIRP 651, male, 99.2 mm SL, Brazil, Minas Gerais State, rio São Francisco, São Roque de Minas municipality, Fazenda Casca D'Anta, 20°30'00"S 46°50'00"W, Dec 1993 – May 1995, L. Casatti, R. M. C. Castro & H. F. Santos.

Paratypes. Minas Gerais State, rio São Francisco. Arapuá municipality. DZSJRP 20129, 5, 19.3–55.4 mm SL (1, 57.9 mm SL) brigde over the ribeirão Bebedouro, on land access to Chaves upstream from Arapuá, 19°02'50"S 46°09'26"W, 920 m asl, 27 Aug

2014, F. Langeani, A. M. Cherobim, B. N. Andrade & A. C. Rosa. São Roque de Minas municipality: LIRP 16932, 25, 19.3–105.1 mm SL (16, 48.8–105.1 mm SL), same data as holotype. MZUSP 50751, (1, 104.3 mm SL), same data as holotype. MZUSP 58677, 10, 37.0–103.3 mm SL (8, 50.2–103.3 mm SL), same data as holotype. DZSJRP 11432, 8, 45.2–86.5 mm SL (3, 61.3–86.5 mm SL), Córrego Grande, surroundings of Parque Nacional Serra da Canastra, owned by Mr. Elmo, 20°20'25"S 46°27'56"W, 19 Jun 2008, R. M. Romero & C. P. Ferreira. DZSJRP 11450, 3, 31.8–74.3 mm SL (2, 65.9–74.3 mm SL), same locality as DZSJRP 11432, 9 Dec 2008, R. M. Romero & G. H. Baviera. DZSJRP 11462, (3, 48.9–79.1 mm SL), Córrego Grande, surroundings of Parque Nacional Serra da Canastra, owned by Mr. Elmo, 20°20'25"S 46°27'56"W, 23 Mar 2009, R. W. Romero & C. A. Roa-Fuentes. DZSJRP 11562, 3, 39.2–108.9 mm SL (2, 102.0–108.9 mm SL), Córrego Cachoeirinha, surroundings of Parque Nacional Serra da Canastra, in front of Brazil Diamond, 20°19'27"S 46°32'15"W, 25 Oct 2009, R. M. Romero & G. H. Baviera. DZSJRP 11568, 1, 61.7 mm SL, same locality as DZSJRP 11562, 7 Nov 2009, R. M. Romero & G. H. Baviera. DZSJRP 11585, 28, 24.4–66.3 mm SL (7, 55.2–66.3 mm SL; 1, c&s), Córrego Lavra, surroundings of Parque Nacional Serra da Canastra, property of Mr. Vitor, upstream bridge, 20°18'36"S 46°25'59"W, 9 Aug 2008, R. M. Romero & A. R. Manzotti. DZSJRP 11597, 7, 50.9–53.9 mm SL (2, 50.9–53.9 mm SL), same locality as DZSJRP 11585, 27 Mar 2009, R. M. Romero & C. A. Roa-Fuentes. DZSJRP 11604, 5, 44.1–68.5 mm SL (2, 51.9–64.2 mm SL), same locality as DZSJRP 11585, 5 Nov 2009, R. M. Romero & G. H. Baviera. DZSJRP 11650, 5, 44.4–84.6 mm SL (4, 48.3–84.6 mm SL), Córrego Luciano, surroundings of Parque Nacional Serra da Canastra, park entrance under bridge, 20°18'46"S 46°31'46"W, 24 Mar 2009, R. M. Romero & C. A. Roa-Fuentes. DZSJRP 20172, (2, 72.1–80.9 mm SL), São José do Barreiro, riacho Grande, road from Vargem Bonita to São José do Barreiro, towards cachoeira da Casca d'Anta, 20°20'10"S 46°27'47"W, 18 Nov 2014, F. Langeani, A. M. Cherobim & B. N. Andrade. DZSJRP 20180, (7, 56.0–82.7 mm SL), São José do Barreiro, on the road from Vargem Bonita to São José do Barreiro, 20°20'00"S 46°28'06"W, 18 Nov 2014, F. Langeani, A. M. Cherobim & B. N. Andrade. DZSJRP 20188, 2, 45.4–81.9 mm SL (1, 81.9 mm SL), stream before the entrance of the Parque Nacional Serra da Canastra, São José do Barreiro, 20°19'16"S 46°31'58"W, 18 Nov 2014, F. Langeani, A. M. Cherobim & B. N. Andrade. INPA 59845, 5, 44.4–60.0 mm SL (1, 60.0 mm SL), same locality as DZSJRP 11585, 5 Nov 2009, R. M. Romero & G. H. Baviera. MCP 54879, 5, 29.8–75.9 mm SL (2, 50.3–75.9 mm SL), same data as DZSJRP 20188. MHNG 2787.091, 5, 38.0–73.0 mm SL, same data as DZSJRP 20180. MNRJ 53314, 5, 30.8–63.2 mm SL (3, 49.6–63.2 mm SL), same data as DZSJRP 20188.

Non-types. Minas Gerais State, rio São Francisco, São Roque de Minas municipality: same locality as DZSJRP 11432: DZSJRP 11441, 4, 27.6–66.5 mm SL, 7 Aug 2008, R. M. Romero & A. R. Manzotti. DZSJRP 11445, 7, 15.3–58.0 mm SL, 8 Oct 2008, R. M. Romero & V. H. M. Prado. DZSJRP 11456, 4, 43.1–98.6 mm SL, 8 Feb 2009, R. M. Romero & G. H. Baviera. DZSJRP 11468, 6, 15.6–40.1 mm SL, Córrego Cerrado, surroundings of Parque Nacional Serra da Canastra, owned by Mr. Joaquim Evaristo, 20°20'0"S 46°28'31"W, 18 Jun 2009, R. M. Romero & C. P. Ferreira. Same locality as DZSJRP 11468: DZSJRP 11474, 12, 16.2–57.2 mm SL, 8 Ago 2008, R. M. Romero & A. R. Manzotti. DZSJRP 11483, 6, 11.7–46.8 mm SL, 9 Oct 2008, R. M. Romero & V.

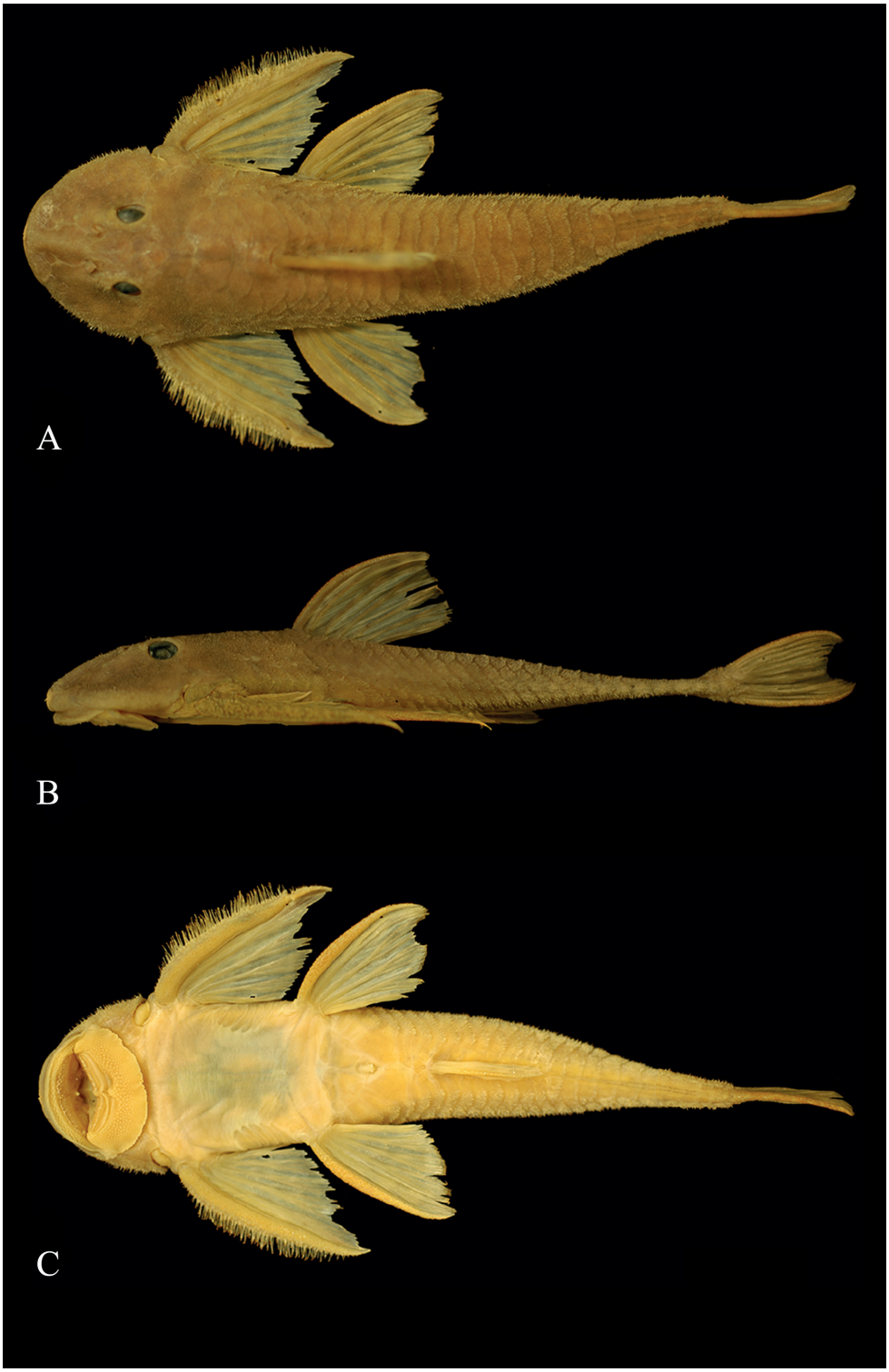

FIGURE 1 | *Harttia canastra*, LIRP 651, male, holotype, 99.2 mm SL, Brazil, Minas Gerais State, rio São Francisco, São Roque de Minas municipality, Fazenda Casca D'Anta. **A.** Dorsal view; **B.** Lateral view; **C.** Ventral view.

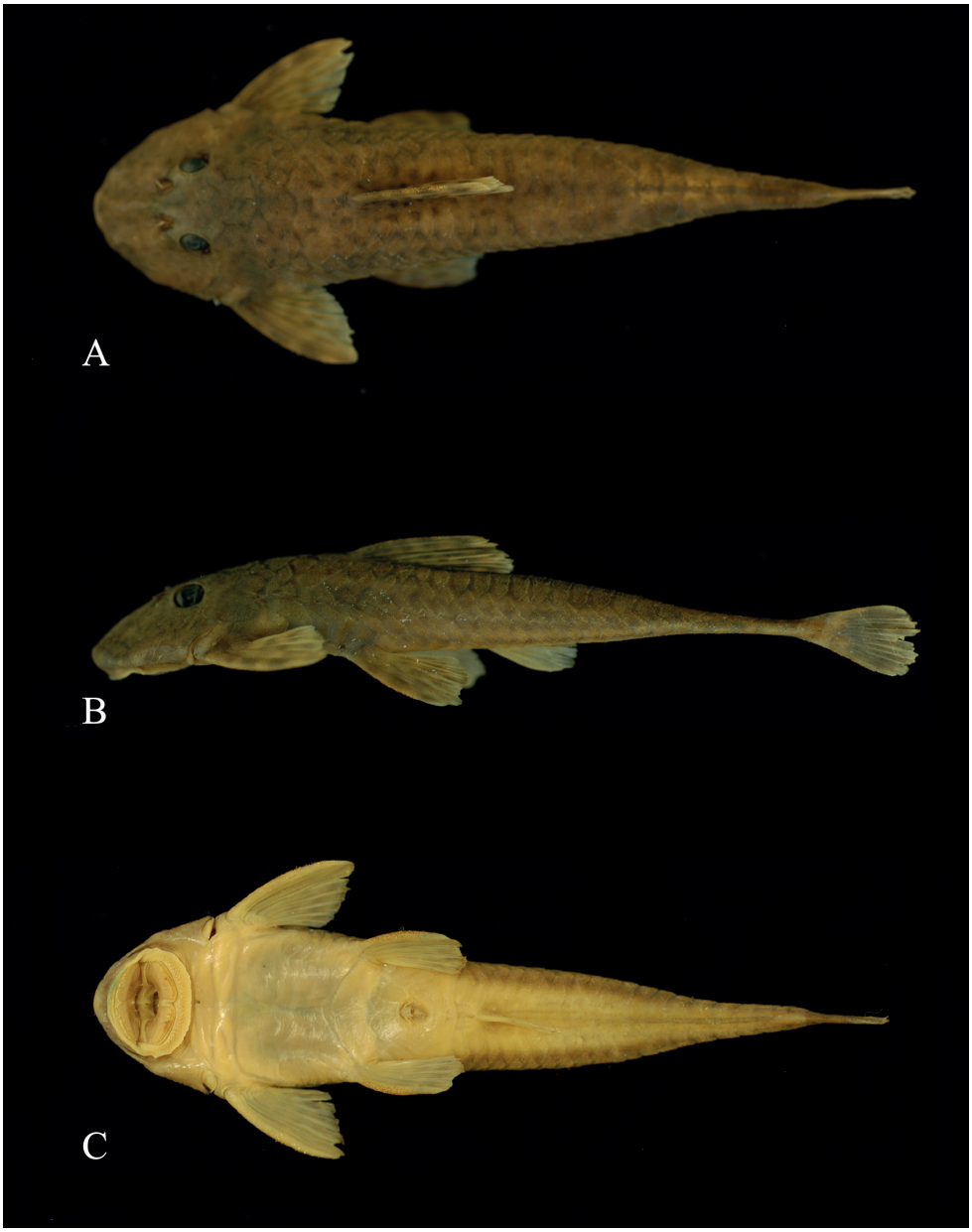

FIGURE 2 | *Harttia canastra*, DZSJRP 20172, female, paratype, 80.9 mm SL, São José do Barreiro, riacho Grande, road Vargem Bonita to São José do Barreiro, towards Cachoeira Casca D'Anta. **A.** Dorsal view; **B.** Lateral view; **C.** Ventral view.

H. M. Prado. DZSJRP 11491, 10, 21.2–46.0 mm SL, 9 Dec 2008, R. M. Romero & G. H. Baviera. DZSJRP 11500, 2, 36.7–39.5 mm SL, 7 Feb 2009, R. M. Romero & G. H. Baviera. DZSJRP 11509, 1, 19.3 mm SL, 25 Mar 2009, R. M. Romero & C. A. Roa-Fuentes. DZSJRP 11516, 12, 52.4–52.5 mm SL, Córrego da Mandioca, surroundings of Parque Nacional Serra da Canastra, São José do Barreiro, Fazenda Passaredo, 20°18'53"S 46°26'22"W, 10 Jun 2008, R. M. Romero & C. P. Ferreira. Same locality as DZSJRP 11516: DZSJRP 11522, 16, 20.0–52.0 mm SL, 9 Aug 2008, R. M. Romero & A. R. Manzotti. DZSJRP 11535, 2, 29.4–31.6 mm SL, 25 Aug 2009, R. M. Romero & G. H. Baviera. DZSJRP 11528, 15, 29.9–53.5 mm SL, Córrego da Mandioca, bridge on the road, surroundings of Parque Nacional Serra da Canastra, São José do Barreiro, Fazenda

Passaredo, 20°18'53"S 46°27'22"W, 8 Jun 2008, R. M. Romero & V. H. M. Prado. DZSJRP 11540, 3, 23.2–43.8 mm SL, same locality as DZSJRP 11528, 5 Nov 2009, R. M. Romero & G. H. Baviera. DZSJRP 11591, 7, 28.1–31.0 mm SL, same locality as DZSJRP 11585, 9 Out 2008, R. M. Romero & V. H. M. Prado. DZSJRP 15826, 1, 28.8 mm SL, same locality as DZSRP 11516, 8 Jun 2008, R. M. Romero and G. H. Baviera. Same locality as DZSJRP 11620: DZSJRP 11626, 6, 55.2–73.0 mm SL, 7 Aug 2008, R. M. Romero & A. R. Manzotti. DZSJRP 11632, 4, 31.1–97.4 mm SL, 24 Mar 2009, R. M. Romero & C. A. Roa-Fuentes.

Diagnosis. The naked abdomen between pectoral- and pelvic-fin girdles readily discriminates *Harttia canastra* from *Harttia absaberi* Oyakawa, Fichberg & Langeani, 2013, *H. dissidens* Rapp Py-Daniel & Oliveira, 2001, *H. duriventris* Rapp Py-Daniel & Oliveira, 2001, *H. fluminensis*, *H. fowleri* (Pellegrin, 1908), *H. longipinna*, *H. panara* Oyakawa, Fichberg & Rapp Py-Daniel, 2018, *H. punctata* Rapp Py-Daniel & Oliveira, 2001, *H. rhombocephala*, *H. rondoni* Oyakawa, Fichberg & Rapp Py-Daniel, 2018, *H. surinamensis* Boeseman, 1971, *H. trombetensis* Rapp Py-Daniel & Oliveira, 2001, *H. tuna*, and *H. villasboas* Oyakawa, Fichberg & Rapp Py-Daniel, 2018 (*vs.* abdomen partially or completely covered by plates; Figs. 3B,C). *Harttia canastra* can be distinguished from *H. carvalhoi* Miranda Ribeiro, 1939, *H. garavelloi* Oyakawa, 1993, *H. intermontana* Oliveira & Oyakawa, 2019, *H. kronei* Miranda Ribeiro, 1908, *H. leiopleura*, and *H. novalimensis* by having preanal plates (*vs.* preanal plates absent; Figs. 3A,D,E). Furthermore, *Harttia canastra* can be distinguished from *H. torrenticola* by having two to four large trapezoidal preanal plates and dorsal-fin spinelet present (*vs.* two to four circular preanal plates and dorsal-fin spinelet absent; Fig. 3F). It differs from *Harttia gracilis* Oyakawa, 1993 in that its lower and upper caudal rays are of same size (*vs.* upper ray slightly longer than the lower one). *Harttia canastra* can be distinguished from *H. guianensis* Rapp Py-Daniel & Oliveira, 2001, *H. loricariformis* Steindachner, 1877, and *H. uatumensis* Rapp Py-Daniel & Oliveira, 2001 by the presence of the dorsal-fin spinelet and by the hypertrophy of odontodes in the lateral region of the head, close to the canal plate, and in the unbranched pectoral fin ray in adult males (*vs.* absence of the dorsal-fin spinelet and males without hypertrophied odontodes). Distinguished from *Harttia depressa* by body depth 40.0–66.7% and head depth 35.7–52.6% of HL (*vs*. extremely depressed body and head, respectively 27.0–33.3% and 31.2–35.7% of HL). It differs from *H. merevari* by having anterior region of head more rounded, darker coloration and adult males with hypertrophied odontodes (*vs*. anterior region of head more triangular, light or dark yellow with many spots and males without hypertrophied odontodes). Finally, in relation to the other species of the rio São Francisco basin, *H. canastra* is distinguished from *H. longipinna* by the absence of plates in the abdominal region between pectoral- and pelvic-fin girdles and by the equivalent anal-fin length both in males and females (respectively 11.7–18.2% and 11.7–18.7% of SL; *vs.* partially covered abdomen and anal-fin length longer in males than in females (respectively 20.0–25.0% and 13.9–16.1% of SL; Fig. 3B); from *H. leiopleura* and *H. novalimensis* for presenting preanal plates (*vs.* preanal plates absent; Figs. 3D,E); and from *H. torrenticola* by having two large preanal trapezoidal plates (*vs.* two to four circular minute preanal plates; Fig. 3F) and the dorsal-fin spinelet (*vs.* dorsal-fin spinelet absent).

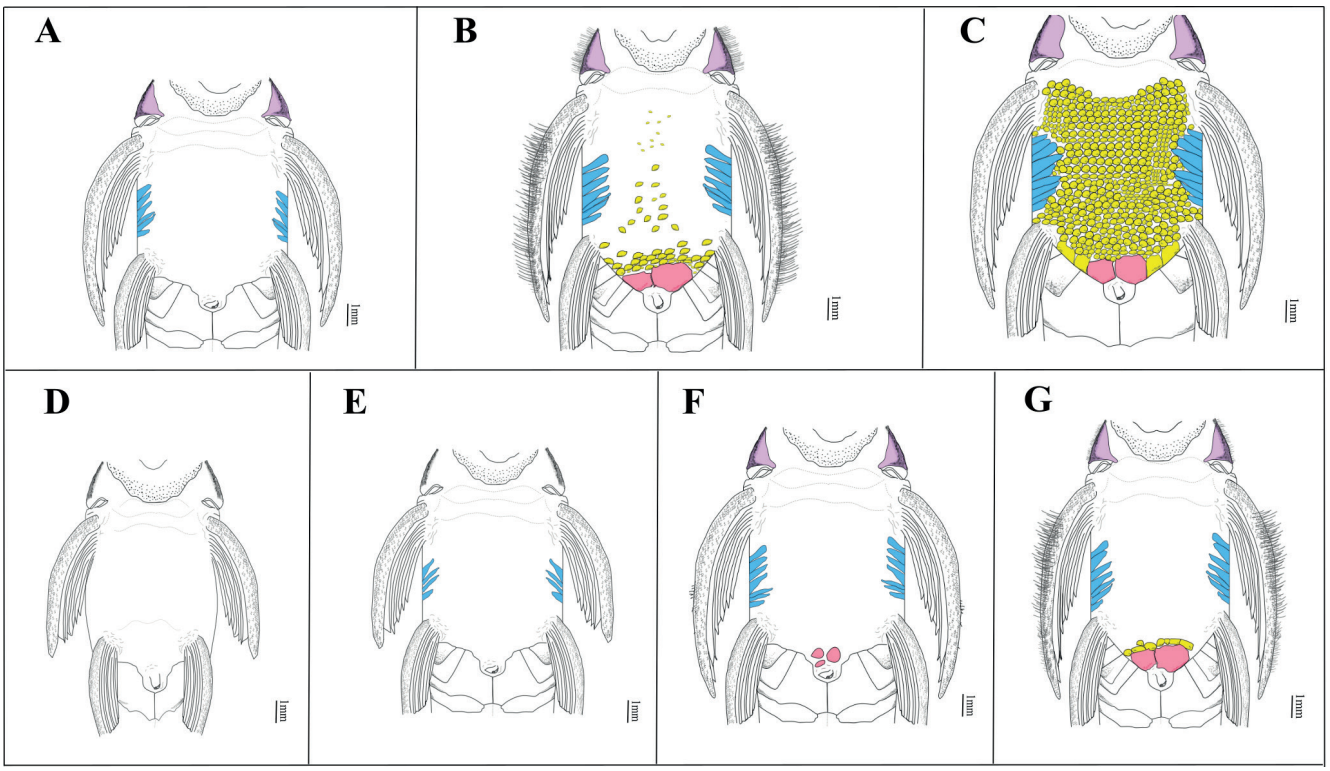

FIGURE 3 | Abdominal (yellow), thoracic (blue), preanal (pink), and canal (purple) plates: (**A**) *Harttia intermontana*, DZSJRP 20978, male, 53.6 mm SL, with a naked abdomen (Group 1), thoracic and canal plates present; (**B**) *Harttia longipinna*, DZSJRP 3666, paratype, male, 82.3 mm SL, with abdomen partially covered by plates (Group 2), preanal, thoracic and canal plates present; (**C**) *Harttia duriventris*, MZUSP 106199, male, 114.9 mm SL, with fully plated abdomen (Group 3), preanal, thoracic and canal plates present; (**D**) *Harttia leiopleura*, MZUSP 109373, 48.3 mm SL, with a naked abdomen (Group 1), preanal, thoracic, and canal plates absent; (**E**) *Harttia novalimensis*, MZUSP 99481, male, 49.0 mm SL, with a naked abdomen (Group 1), thoracic plates present, and preanal and canal plates absent; (**F**) *Harttia torrenticola*, MZUSP 94482, male, 85.5 mm SL, with a naked abdomen (Group 1), preanal, thoracic, and canal plates present; (**G**) *Harttia canastra*, LIRP 651, male, holotype, 99.2 mm SL, with a naked abdomen (Group 1), preanal, thoracic, and canal plates present.

Description. Examined material: 247 specimens (68 measured and counted). Small size, 48.3–108.9 mm SL (Tab. 2). Body depressed and elongated, wider at cleithrum, progressively narrower from origin of pectoral fin to caudal peduncle. Dorsal profile convex from tip of snout to anterior region of dorsal fin, gently descending to caudal peduncle. Ventral profile of body straight from tip of snout to origin of anal fin, then gently ascending to caudal peduncle. Anterior region of head elliptical in dorsal view. Orbit rounded, preorbital crest rudimentary (crest not as prominent as in Amazonian *Harttia* species), inferior margin of orbit approximately straight (margin not as straight as *Harttia loricariformis*). Snout tip naked. Maxillary barbel rudimentary and joined to lips. Lower lip larger than upper lip, both papillose. Lower lip usually reaching posterior margin of coracoid. Infraorbital sensory canal in six plates. Canal plate present. Premaxillary with 30–67 (40) and dentary with 29–70 (38) rounded, bicuspid, and subequal teeth. Abdominal plates between pectoral- and pelvic-fin girdles absent; two to four large and trapezoidal preanal plates, sometimes bordered by small plates; specimens smaller than 60 mm SL usually with no preanal plates. Five longitudinal series of plates on body: dorsal series, 19–27 (24) plates; mid-dorsal series, 12–20 (17) plates; median series, 25–30 (27) perforated plates; mid-ventral series, 14–21 (17) plates;

TABLE 2 | Measurements and counts of *Harttia canastra*. Standard length (mm), percentages of body measurements in relation to standard length (SL) or percentage of head measurements in relation to head length (HL). Dorsal fin origin (D), anal fin origin (A), caudal fin origin (C), standard deviation (SD). Total number of analyzed type-specimens=68.

Measurements	Holotype	Min-Max	Mean	SD
Standard length	99.2	48.3–108.9	69.4	–
Percents of standard length				
Head length	26.9	24.6–30.8	27.0	1.3
Body depth	12.0	11.9–17.4	14.2	1.4
Body width	21.6	16.8–24.9	20.5	1.7
Body width (A)	16.7	12.3–21.8	15.6	1.4
Body width (C)	4.0	2.4–5.7	3.6	0.5
Predorsal length	37.2	35.1–41.1	38.0	1.3
Post-dorsal length	48.7	47.6–57.3	51.4	2.3
Post-anal length	38.3	36.7–47.5	42.4	2.4
Dorsal fin length	24.6	20.4–30.3	24.2	1.6
Pectoral fin length	31.6	20.4–31.7	24.9	2.2
Pelvic fin length	24.8	16.6–26.7	22.0	2.0
Anal fin length	17.3	11.7–18.7	15.2	1.5
Trunk length	20.6	16.5–22.8	19.3	1.4
Head depth	12.1	10.6–15.4	12.6	0.9
Percents of head length				
Head width	94.8	77.9–98.9	89.3	4.7
Cleithral width	27.3	23.6–28.7	26.2	1.3
Eye diameter	12.0	9.3–17.8	13.9	1.6
Interorbital width	27.7	24.3–33.6	29.3	2.0
Snout length	59.2	50.4–63.4	57.4	3.5
Counts		**Mode**		
Median series plates	27	25–30	27	
Dorsal series plates	24	19–27	24	
Mid-Dorsal series plates	17	12–20	17	
Mid-Ventral series plates	19	14–21	17	
Ventral series plates	22	19–23	22	
Thoracic plates	8	3–8	5	
Dorsal-caudal plates	17	14–18	16	
Anal-caudal plates	14	12–16	14	
Premaxillary teeth	48	30–67	40	
Dentary teeth	43	29–70	38	

ventral series, 19–23 (22) plates. Three to eight (five) rectangular and elongated lateral thoracic plates; plates between dorsal and caudal fin, 14–18 (16); plates from anal to caudal fin, 12–16 (14); two long, poreless supracaudal plates on the lateral line. Dorsal fin, II,7; dorsal-fin spinelet present; anal fin, i,5; pectoral fin, I,6; pelvic fin, i,5; caudal fin, i,12,i, forked, upper and lower unbranched rays subequal. Caudal peduncle, viewed from above, slightly more tapered after confluence of lateral plates series.

Coloration in alcohol. Light brown body with brown spots along dorsal region, forming four inconspicuous transverse bands, starting at origin of dorsal fin; ventral region light yellow. Pectoral, dorsal, pelvic, anal and caudal-fin rays with dark brown spots, interradial membrane hyaline.

Sexual dimorphism. Males with hypertrophied odontodes in the first pectoral-fin ray and in the lateral region of the head, close to the opercular opening, and an elongated urogenital papilla (*vs.* females without developed odontodes and with a short urogenital papilla, resembling a pore) (Figs. 1–2).

Geographical distribution. Several locations in the rio São Francisco basin, mainly headwater streams around the Parque Nacional Serra da Canastra, Municipality of São Roque de Minas, State of Minas Gerais (Fig. 4).

Ecological notes. *Harttia canastra* type locality consisted of an approximately 60 m riffle stretch with substrate consisting of sand, gravel, and rocks, current ranging 0.3–2.3 m.s-1, width from 4–13 m, depth from 0.5–1.2 m, discharge from 1.8–3.2 $m^3.s^{-1}$,

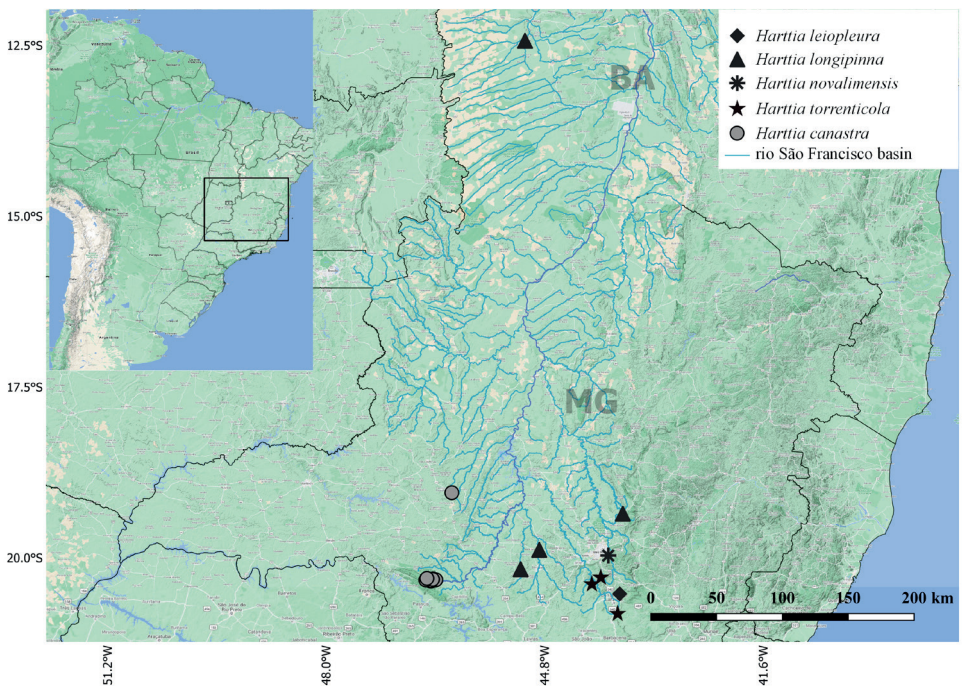

FIGURE 4 | Distribution map of *Harttia* species from the rio São Francisco basin.

subaquatic horizontal transparency from 1.6– 9.6 m, air temperature from 10–31.5°C, water temperature from 12.4–23°C, and dissolved oxygen from 8.9–21.7 mg.l^{-1} (Casatti, Castro, 1998, 2006). Romero, Casatti (2012) and Roa-Fuentes *et al*. (2015) presented additional information about other localities where most of the paratypes were collected, and also about other species inhabiting the same sites. Other species occurring with *Harttia canastra* include: *Apareiodon ibitiensis* Amaral Campos, 1944, *A. piracicabae* (Eigenmann, 1907), *Cetopsorhamdia iheringi* Schubart & Gomes, 1959, *Characidium fasciatum* Reinhardt, 1867, *C. zebra* Eigenmann, 1909, *Creagrutus varii* Ribeiro, Benine & Figueiredo, 2004, *Harttia* cf. *novalimensis*, *Hisonotus alberti* Roxo, Silva, Waltz & Melo, 2016, *Hoplias malabaricus* (Bloch, 1794), *Hypostomus garmani* (Regan, 1904), *Neoplecostomus canastra* Roxo, Silva, Zawadzki & Oliveira, 2017, *Oreochromis niloticus* (Linnaeus, 1758), *Parodon hilarii* Reinhardt, 1867, *Phalloceros* sp., *Piabarchus stramineus* (Eigenmann, 1908), *Piabina argentea* Reinhardt, 1867, *Psalidodon rivularis* (Lütken, 1875), *Rhamdia* aff. *quelen* (Quoy & Gaimard, 1824), *Trichomycterus brasiliensis* Lütken, 1874, *T. reinhardti* (Eigenmann, 1917), *T. variegatus* Costa, 1992 (all of them deposited at the DZSJRP fish collection).

Etymology. The name "*canastra*" refers to the Serra da Canastra, a mountain range located in the center-south of the state of Minas Gerais, which houses the headwaters of the rio São Francisco, where most of the specimens were collected. A noun in apposition.

Conservation status. The species was sampled in various localities in the rio São Francisco basin, some of them very near the Parque Nacional da Serra da Canastra, a national conservation unit. This large distribution, together with its abundance and frequency of capture, suggests that *Harttia canastra* can be categorized as Least Concern (LC) according to the International Union for Conservation of Nature (IUCN) categories and criteria (IUCN Standards and Petitions Subcommittee, 2022).

Key to species of *Harttia* from the rio São Francisco basin

1a. Canal plate and preanal plates present 2
1b. Canal plate and preanal plates absent 4
2a. Abdomen region between pectoral- and pelvic-fin girdles naked; anal-fin size equivalent in males and females (respectively, 11.7–18.2% and 11.7–18.7% of SL) 3
2b. Abdomen region between pectoral- and pelvic-fin girdles partially covered by plates; anal-fin size in adult males longer than in females, respectively 20–25% and 13.9–16.1% of SL ..... *H. longipinna*
3a. Two to four small and circular pre-anal plates; dorsal-fin spinelet absent ..... *H. torrenticola*
3b. Two large and trapezoidal pre-anal plates, sometimes with small plates around them; dorsal-fin spinelet present ..... *H. canastra*
4a. Thoracic plates absent; five infraorbital plates; seven branched rays on the pectoral fin ..... *H. leiopleura*
4b. Three to five thoracic plates; six infraorbital plates; six branched rays on the pectoral fin ..... *H. novalimensis*

DISCUSSION

In the last 10 years, seven new *Harttia* species were described, two for the Guiana Shield drainages (Covain *et al*., 2012) and five for the Brazilian Crystaline Shield drainages (Oyakawa *et al*., 2013, 2018; Oliveira, Oyakawa, 2019). The Brazilian Crystalline Shield southeastern basins, with the headwaters of the rios Doce, Grande, Jequitinhonha, Paraíba do Sul and São Francisco, and also smaller coastal basins, drain the southern portions of the Espinhaço Complex and western portions of the Serra da Mantiqueira. Most of its species occur in forested headwater streams, with sandy and rocky bottoms, and clear, cold and fast-flowing water (Casatti, Castro, 1998, 2006; Romero, Casatti, 2012; Oyakawa *et al*., 2013; Roa-Fuentes *et al*., 2015; Oliveira, Oyakawa, 2019). *Harttia longipinna*, on the contrary, inhabits large rivers (Langeani *et al*., 2001; our data), and in this respect is more similar to species of the Amazon, Orinoco, and Guiana Shield basins (Rapp Py-Daniel, Oliveira, 2001; Provenzano *et al*., 2005; Covain *et al*., 2012; Oyakawa *et al*., 2018; our data; L. Rapp Py-Daniel, 2022, pers. comm.). The smaller environments, apparently preferred by these southeastern *Harttia* species, are now significantly altered (Oliveira, Oyakawa, 2019), which seems to have contributed to the restriction of their distribution into reduced areas.

The pattern of plates in the body ventral region is very important in discriminating *Harttia* species, comprising the preanal plates, thoracic plates, abdominal plates, and canal plate, as already noted by Oyakawa (1993), Rapp Py-Daniel, Oliveira (2001), Langeani *et al.* (2001), Provenzano *et al.* (2005), Oyakawa *et al.* (2013, 2018), and Oliveira, Oyakawa (2019). However, the definition of each of these plates can be confusing to non-experts in the group and non-taxonomists. Thus, we present a clearer delimitation of these plates based on our interpretation of previously published description articles. The preanal plates are those strictly close to the anus and the urogenital pore (Fig. 3, pink). The thoracic plates are the ones on the sides of the body, between the pectoral and pelvic girdles (Fig. 3, blue). The abdominal plates correspond to all the other plates that appear in the ventral region, between the pectoral girdle and the preanal plates (Fig. 3, yellow). Finally, the canal plate is an approximately triangular plate located ventrally to the preopercle that bears the final portion of the preopercular ramus of the laterosensory canal (Schaefer, 1987, 1991; Armbruster, 2004; Pereira, Reis, 2017) (Fig. 3, purple).

Additionally, to better understand the three types of abdominal plates coverage proposed by Oyakawa *et al*. (2018), it is necessary to observe the area between the pectoral and pelvic girdles. The abdomen completely covered by plates represents the condition where there are abdominal plates along the entire area between the two girdles (Fig. 3C). In the abdomen partially covered, there are regions with and without abdominal plates between the two girdles, the proportion of each vary depending on the species (Fig. 3B). In the last condition, *e.g*., the abdomen naked, there are no abdominal plates between the two girdles (Fig. 3A,D,E,F), although in some cases abdominal ones might be present around the preanal plates, after the pelvic girdle (Fig. 3G). Therefore, *Harttia canastra* is readily distinguished from species of the genus, including its congeners of the rio São Francisco basin, due to the following plate pattern combination: two to four large and trapezoidal preanal plates (sometimes bordered by small abdominal plates), abdomen naked (no abdominal plates between the two girdles), and thoracic and canal

plates present. In this respect, it is worth mentioning that among the comparative material from the rio São Francisco basin we have observed specimens of *H. longipinna* (MCNIP 1584 and 1588) with and without abdominal plates, and specimens here identified as *H.* cf. *novalimensis* (DZSJRP 11612, 11620, and 2016) with a canal plate, features not mentioned until now for those two species (Oyakawa, 1993; Langeani *et al*., 2001; Oyakawa *et al*., 2013, 2018; Oliveira, Oyakawa, 2019); this intraspecific variation should be better analyzed by a future taxonomic revision of *Harttia* from the rio São Francisco basin.

Furthermore, Cherobim (2022) performed a morphological and molecular phylogenetic analysis of the genus *Harttia* and included *H. canastra*. It is referred to as *Harttia* sp. São Roque in the morphological analysis, and *Harttia* sp. São Francisco in the molecular analysis. In the morphological phylogeny, Cherobim (2022) recovered a monophyletic group composed of: (*H. canastra*, São Francisco basin + (*H. carvalhoi*, Paraíba do Sul basin + (*H. intermontana*, Doce basin + *H. torrenticola*, São Francisco basin))). In the molecular phylogeny, another monophyletic group was recovered with the same species, but in a different topology: (*Harttia carvalhoi* + (*H. intermontana* + (*H. canastra* + (*H. torrenticola* + *H. canastra*)))). This unexpected result in the molecular analysis, with a paraphyletic *H. canastra*, led us to check those previous identifications. Some samples previously identified in Cherobim (2022) as *Harttia canastra* (DZSJRP 16126), which resulted as sister to *H. torrenticola* as in the relationships mentioned above, are in fact belonging to *H. torrenticola*. Therefore, the molecular hypothesis of Cherobim (2022) would actually be: (*Harttia carvalhoi* + (*H. intermontana* + (*H. canastra* + (*H. torrenticola* + *H. torrenticola*)))), resulting in *H. canastra* as sister to *H. torrenticola*. According to Cherobim (2022), the establishment of a correlation between the phylogenetic relationships among these species and their geographic distribution pattern, does not result in a simple explanation, demonstrating the complexity of this area, and its biogeographic discontinuity as previously highlighted by Ribeiro (2006) and Buckup (2011). The Brazilian Shield is a region characterized by many ancient faults from the time of Gondwana breakup, and also recent tectonic stresses and differential erosions that finally lead to stream captures. So, the "exchange of fauna among these basins was probably due to the continuity of these processes throughout history" (Cherobim, 2022). Besides, an increase in the diversity of the genus is expected in the rio São Francisco basin, as well as in the area of distribution of the species as the drainage becomes better sampled.

Comparative material examined. All from Brazil except otherwise noticed. *Harttia absaberi*: Mato Grosso do Sul State, upper rio Paraná basin, MZUSP 85806, 5 of 34 paratypes, (1 of 2 c&s), 56.4–42.2 mm SL. *Harttia carvalhoi*: Rio de Janeiro State, rio Paraíba do Sul, DZSJRP 20358, 3, 40.0–45.7 mm SL. São Paulo State, Pindamonhangaba, rio Paraíba do Sul; MZUSP 44505, 1 c&s; MZUSP 79367, 2, 68.8–75.9 mm SL. *Harttia dissidens*: Pará State, Itaituba municipality, INPA 7046, 2 of 22, (1 c&s), 108.6–126.5 mm SL. *Harttia duriventris*: Pará State, Marabá municipality, rio Itacaiúnas, MZUSP 34226, 4 of 26, 72.2–100.3 mm SL; MZUSP 106199, 2, 99.5–114.9 mm SL. *Harttia fowleri*: Amapá State, Porto Marcirio municipality, rio Araguari, INPA 7845, 2 of 49, (1 c&s), 105.4–142.3 mm SL. *Harttia garavelloi*: Minas Gerais State, rio Jequitinhonha, MZUSP 42696, 1 of 2 paratypes, c&s; MCP 49359, 18, 30.4–63.3 mm SL; MZUSP 94430, 3, 53.4–75.0 mm SL. *Harttia gracilis*: Minas Gerais State, Passos and Itaú de Minas municipalities, rio Grande, DZSJRP 17746, 1, 101.3 mm SL. São Paulo State, São Bento do Sapucaí municipality, rio Grande, MZUSP 99678, 7 of 29, (1 c&s), 38.5–83.1 mm SL. *Harttia guianensis*: French Guyana, Saut. Deux Roros, INPA 14985, 1 of 4, (1 c&s), 63.8-86.3 mm SL. *Harttia*

intermontana: Minas Gerais State, rio Doce, DZSJRP 16150, 23, 43.5–46.0 mm SL; DZSJRP 19145, 2, 27.6–45.5 mm SL; DZSJRP 20069, 38, (1 c&s), 26.8–51.3 mm SL; DZSJRP 20978, 47: 33.0–53.6 mm SL; DZSJRP 22636, 5, 14.4–72.2 mm SL. *Harttia kronei*: São Paulo State, rio Ribeira de Iguape, MZUSP 10602, 2, 70.3–77.6 mm SL; MZUSP 42694, 1 c&s; MZUSP 53811, 9, 71.3–94.1 mm SL; DZSJRP 13697, 3, 51.9 mm SL. *Harttia leiopleura*: Minas Gerais State, Caeté, rio São Francisco, MZUSP 109373, 3, (1 c&s), 38.4–48.3 mm SL. Minas Gerais state, Ouro Preto, rio São Francisco, MZUSP 109426, 2, 43.2–45.2 mm SL. *Harttia longipinna*: Bahia State, São Desidério, rio São Francisco, DZSJRP 3666, 6 paratypes, (2 c&s), 48.6–84.7 mm SL. Minas Gerais state, rio São Francisco, DZSJRP 2819, 1 paratype, 84.0 mm SL; MCNIP 1584, 19, 29,6–90.1 mm SL; MCNIP 1588, 2, 56.7–98.5 mm SL; MZUSP 39145, 5, 64.0–80.0 mm SL; MZUSP 73692, 1, 108.6 mm SL. *Harttia loricariformis*: Minas Gerais State, Muriaé municipality, rio Paraíba do Sul, MZUSP 80954, 4, 61.8–117.9 mm SL. Rio de Janeiro State, São Fidélis municipality, rio Paraíba do Sul, DZSJRP 21103, 2, 130.3–131.4 mm SL. São Paulo State, rio Paraíba do Sul, MZUSP 2163, 1 c&s. *Harttia novalimensis*: Minas Gerais State, Nova Lima municipality, rio São Francisco, MZUSP 37147, 1 paratype, c&s, 55.4 mm SL; MZUSP 94481, 3 of 28, 44.5–49.7 mm SL. *Harttia* cf. *novalimensis*: Minas Gerais State, São Roque de Minas municipality, rio São Francisco, DZSJRP 11612, (2, 55.3–61.9 mm SL), Córrego Lavra, surroundings of Parque Nacional Serra da Canastra, property of Mr. Vitor, upstream bridge, 20°18'36"S 46°25'59"W, 9 Aug 2008; DZSJRP 11620, 4, 22.3–72.7 mm SL (3, 48.4–72.7 mm SL), Córrego Luciano, surroundings of Parque Nacional Serra da Canastra, park entrance under bridge, 20°18'46"S 46°31'46"W, 16 Jun 2008; DZSJRP 20166, 2, 47.9–72.3 mm SL (1, 71.2 mm SL), creek on the Vicinal on the right, unpaved road, São Roque de Minas to São José do Barreiro, before the Vargem Bonita, 20°19'19"S 46°23'27"W, 18 Nov 2014. *Harttia panara*: Pará State, rio Curuá, MZUSP 97088, 1 of 3 paratypes, c&s; MZUSP 118551, 1 of 2 paratypes, 89.9 mm SL. *Harttia punctata*: Goiás State, rio Tocantins, DZSJRP 22659, 1, 67.3 mm SL; MCP 15873, 2, 59.9–60.0 mm SL; MZUSP 15873, 2, 58.3–60.5 mm SL; MZUSP 96172, 5, (1 c&s), 65.8–92,7 mm SL. Maranhão State, rio Tocantins, DZSJRP 20764, 1, 72.2 mm SL; DZSJRP 20702, 1, 98.3 mm SL. *Harttia rondoni*: Pará State, Altamira municipality, rio Curuá, MZUSP 97083, 1 of 9 paratypes, c&s; MZUSP 97085, 9 paratypes, 90.3–109.7 mm SL. *Harttia surinamensis*: Amapá State, rio Cupixi, MZUSP 34224, 3 of 60, (1 c&s), 104.7–132.3 mm SL. *Harttia torrenticola*: Minas Gerais State, Belo Vale municipality, rio São Francisco, MZUSP 94482, 2, 69.4–85.5 mm SL. Cristiano Otoni municipality, rio São Francisco, DZSJRP 5725, 1 c&s, 51.8 mm SL; DZSJRP 16126, 21, 25.2–35.1 mm SL; DZSJRP 20970, 2, 20.0–30.8 mm SL; DZSJRP 20090, 9, 29.3–35.7 mm SL. *Harttia trombetensis*: Pará State, Oriximiná municipality, rio Trombetas, INPA 3011, 3 (1 c&s), 79.4–90.7 mm SL. *Harttia uatumensis*: Amazonas State, INPA 12954, 2, 74.0–87.7 mm SL; INPA 3239, 1, 105.8 mm SL. **Suriname**, MZUSP 107732, 2 of 11, (1 c&s), 131.8–132.5 mm SL. *Harttia villasboas*: Pará State, Altamira municipality, rio Curuá, MZUSP 115485, 2 of 58 paratypes, (1 of 6 c&s), 87.4–93.5 mm SL. *Harttia* sp. 1: Minas Gerais State, Delfim Moreira municipality, rio Grande, DZSJRP 20587, 1, 28.2 mm SL; DZSJRP 20588, 2, 110.0–116.6 mm SL. *Harttia* sp. 2: Pará State, rio Braço Norte, MZUSP 116594, 2, 89.6–89.9 mm SL; MZUSP 97079, 2 of 81, 100.2–106.2 mm SL.

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AUTHORS' CONTRIBUTION

Laís Caldas: Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing-original draft, Writing-review and editing.

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