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Inventory

Marine ichthyofauna of Santa Catarina Island, Southern Brazil: checklist with comments on the species

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Abstract: This study aimed to present a checklist of marine fishes from coastal environments of the Island of Santa Catarina, including comments on the zoogeographic affinities, conservation status of each species, and functional groups. A total of 169 fish species belonging to 30 orders and 58 families were recorded. The most speciose families were Sciaenidae, Carangidae and, Engraulidae, representing 26,62% of the recorded species. *Anchoa* was the richest genus, followed by *Sphoeroides* and *Cynoscion*. Most of the species have their distribution limited to the western Atlantic, and two groups of fish were distinguished according to the species distributions: 1) species occurring in the Caribbean and in the Brazilian Province; and 2) Transatlantic species. Thirteen species are critically threatened, 10 are overexploited on the Brazilian coast, and 2 are threatened by extinction. Most of the species are either marine stragglers or marine migrants, and most of them are zoobenthivores, piscivores, or both.

Keywords: *fish, species list, Southwest Atlantic.*

Ictiofauna marinha da Ilha de Santa Catarina, Sul do Brasil: lista com comentários sobre as espécies

Resumo: Este estudo teve como objetivo apresentar uma lista de peixes marinhos de ambientes costeiros da Ilha de Santa Catarina, incluindo comentários sobre as afinidades zoogeográficas, estado de conservação de cada espécie e grupos funcionais. Um total de 169 espécies de peixes, pertencentes a 30 ordens e 58 famílias, foram registradas. As famílias mais especiosas foram Sciaenidae, Carangidae e Engraulidae, representando 26,62% das espécies registradas. *Anchoa* foi o gênero mais rico, seguido por *Sphoeroides* e *Cynoscion*. A maioria das espécies tem sua distribuição limitada ao Atlântico ocidental, e dois grupos de peixes foram distinguidos de acordo com as distribuições de espécies: 1) espécies ocorrentes no Caribe e na Província Brasileira; e 2) espécies Transatlânticas. Treze espécies estão criticamente ameaçadas, 10 são superexploradas na costa brasileira e 2 estão ameaçadas de extinção. A maioria das espécies é composta por visitantes marinhos ou migrantes marinhos, sendo a maioria deles zoobentívoros, piscívoros ou ambos.

Palavras-chave: *peixe, lista de espécies, Atlântico Sudoeste.*

Introduction

Diversity of estuarine environments is threatened by anthropogenic activities such as predatory fishing and port construction and activities, which can lead to species introduction, habitat loss, and environmental pollution. Thus, the compilation of fish records from South Atlantic is important because it improves the understanding of the geographic distribution and macroecological aspects of marine and estuarine fishes (Barletta & Blaber 2007), and assists in strategic planning for the conservation of the species as well (Barletta et al., 2010).

Coastal and estuarine areas are nurseries for the aquatic biota. Despite the great variety of ecosystems, knowledge about fish assembly from the Island of Santa Catarina is scarce. Only a few studies have been conducted, which focused on spatio-temporal patterns in specific environments (Clezar et al. 1997, Ribeiro et al. 1997, Ribeiro et al. 1999, Cartagena et al. 2011, Soeth 2015). Therefore, this study aimed to present a checklist of marine fishes from different coastal environments of the Island of Santa Catarina through a compilation of unpublished and published information from the literature. In addition, comments on the zoogeographic affinities, conservation status of each species, and functional groups are also provided.

Material and Methods

1. *Study Site*

The Island of Santa Catarina (28°37'S; 48°27'W) (Figure 1) is located near the tropical/subtropical border, and parallelly and contiguously to the continental margin. It has an elongated shape (N-NE/S-SW), an area of 431 km^2, and a coastline length of 180 km (Sierra de Ledo 1997). It is an insular environment composed by a variety of ecosystems, such as mangroves, lagoons, sandy beaches and rocky shores. Regarding its climate, the region is humid subtropical (Köppen Cfa), characterized by a well-defined seasonality, with the rainy period in the spring and summer (September to March, with monthly mean of 172 mm), and the dry period in the autumn and winter (April to August, with monthly mean of 74 mm) (Fonseca 2002).

The predominant wind patterns on the island is associated with the action of the Tropical Atlantic and Polar Atlantic air masses, which produce winds from the north and south quadrants, respectively (Abreu de Castilhos and Gré 1997). According to these authors, the dominant waves are mainly from the northeast, southeast and south, with the most significant heights coming from the south. The island also has semidiurnal tides (mean amplitude = 0.52 m) in the interior of the bays in the area near the island (Soriano-Sierra 1997).

2. *Data Collection*

This work was based on the compilation of information available in the literature as well as unpublished data obtained by the authors during the last 30 years. Former data was obtained from Google Scholar, Web of Science, and Portal de Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). We searched for articles focusing on fish species from different environments (e.g. bays, lagoons and mangroves) of the Island of Santa Catarina (e.g. Clezar et al.1997, Nemar 1999, Daura Jorge 2007, Cartagena et al. 2011, Soeth 2015, Cattani et al., 2016a, Cattani et al., 2016b, Cattani et al., 2018).

3. *Data Analysis*

Taxonomic classification and nomenclature of fish species followed Craig & Hastings (2007), Smith & Craig (2007), Eschmeyer (2013), Carvalho-Filho et al. (2010), Figueiredo et al. (2010), Menezes et al. (2010) Nelson et al. (2016) and Betancur-R et al. (2017). *Mugil* sp. was used for species usually identified under the invalid name *Mugil gaimardianus* (Menezes et al. 2003). Orders and families are listed in alphabetical order, and species of each family are presented in alphabetical order as well.

In order to analyze the zoogeographic affinities, we classified each species according to the literature (Floeter et al. 2008, Luiz Jr. et al. 2008, Eschmeyer 2013, Froese & Pauly 2018) in the following categories of geographic distribution: CT = Circumtropical, TA = Transatlantic (occurs in western and eastern Atlantic Ocean), WA = Western Atlantic (occurs in northern and southern Atlantic Ocean), SWA = Southwestern Atlantic (occurs from northern Brazil to Argentina), SSWA = Southern Southwestern Atlantic (species with temperate affinities that occurs in Argentina, Uruguay, and southern and southeastern Brazil), Ca = Caribbean (from Florida to Venezuela), Br = Brazilian Province (area between the Orinoco Delta in Venezuela and Santa Catarina state, in Brazil: *sensu* Briggs 1995; Floeter & Gasparini 2000) and EP = Eastern Pacific. Species were also classified according to the type of environment they were collected (bays, lagoons and mangroves).

Fish species were classified into the following estuarine functional groups, proposed by Elliot et al. (2007): marine stragglers (MS) (species that spawn at sea and enter estuaries in low numbers; stenohaline environments with salinity around 35), marine migrants (MM) (species that spawn at sea and enter estuaries in large numbers as juveniles; euryhaline environments), estuarine species (ES), anadromous (AN) (species that undergo their growth at sea and migrate into rivers to spawn), amphidromous (AM) (migrate between the sea and freshwater; migration in neither direction is related to reproduction), and freshwater migrants (FM) (found in moderate numbers in estuaries and oligohaline environments). Species were also classified into trophic functional groups (Elliot et al. 2007): zooplanktivore (ZP) (feeds on zooplankton), detritivore (DV) (feeds on detritus and/or microphytobenthos), herbivore (HV) (grazes on macroalgae and macrophytes or phytoplankton), omnivore (OV) (feeds on filamentous algae, macrophytes, periphyton, epifauna and infauna), piscivore (PV) (feeds on finfish and large nektonic invertebrates), zoobenthivore (ZB) (feeds on invertebrates that live just above, on or in the sediment) and opportunist (OP) (feeds on a diverse range of food).

The conservation status of each species followed the International Red List of threatened species proposed by the IUCN (2018), by the Brazilian red list of threatened species proposed by the MMA (2016), and by regional conservation status based on the list proposed by State Council of the Environment of Santa Catarina - CONSEMA (2011). All specimens were deposited in the fish collection of the Núcleo de Estudos do Mar - NEMAR, Universidade Federal de Santa Catarina.

Results

The ichthyofauna of the Island of Santa Catarina comprises 169 species (165 Actinopterygii and 4 Elasmobranchii) distributed into 30 orders and 58 families. Perciformes was the most speciose order (32), followed by Clupeiformes (18), Pleuronectiformes (14) and

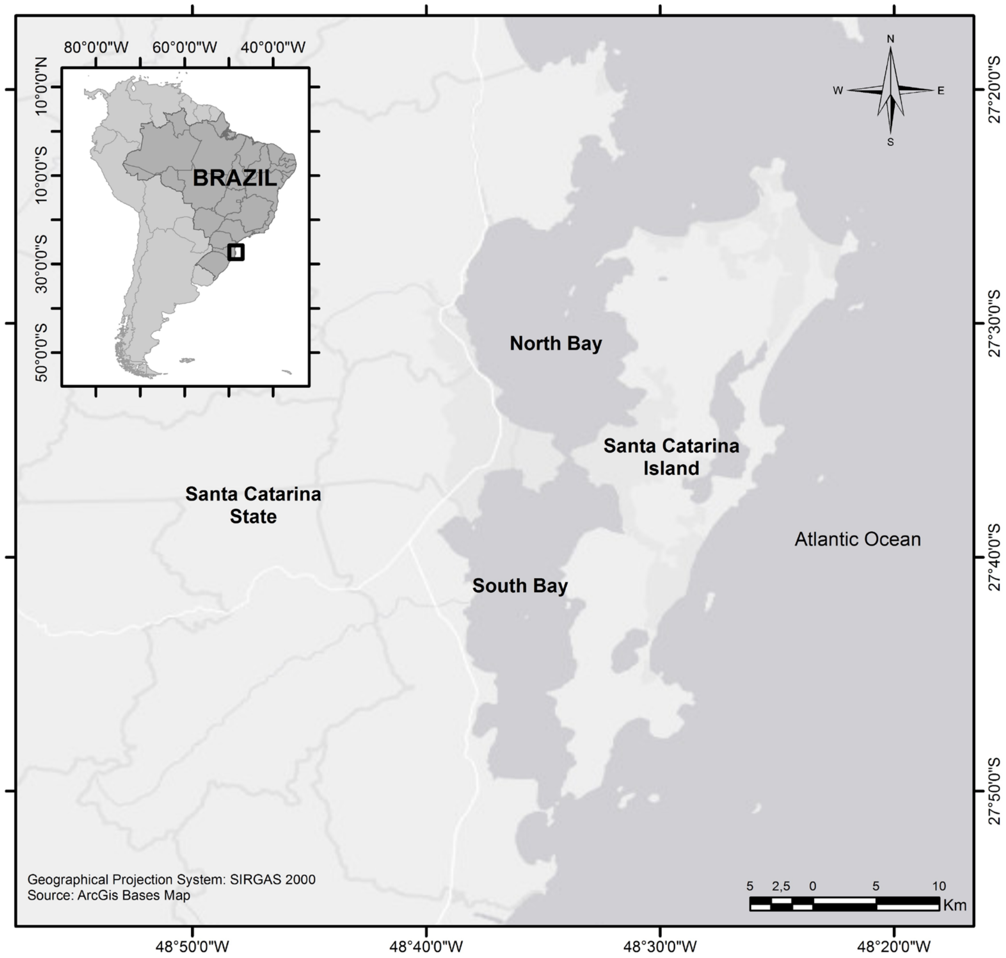

Figure 1. Location of the Island of Santa Catarina, Southern Brazil.

Tetraodontiformes (13) (Table 1). Concerning the families, Sciaenidae was the most recorded (20), followed by Carangidae (14), Engraulidae (11), Epinephelidae and Gobiidae (8 each). *Anchoa*, *Sphoeroides* and *Cynoscion* were the richest genera, with 6, 5 and 4 species, respectively.

Regarding the geographic distribution, 37,86% (64) occur in the Western North Atlantic, 14,20% (24) occur on both sides of the Atlantic, 13,01% (22) occur in the Caribbean and in the Brazilian Province, 9,46% (16) occur only in the Southern Southwestern Atlantic, 5,91% (10) occur in the Caribbean and in the Southwestern Atlantic, 4,73% (8) are distributed in tropical areas worldwide, 4,14% (7) occur only in the Southwestern Atlantic, 3,55% (6) occur only in the Brazilian Province, 2,36% (4) occur in the Western Atlantic and in the Eastern Pacific, 0,59% (1) occur in the Brazilian Province and in the Southwestern Atlantic and 1,18% (2) occur on both sides of the Atlantic and in the Eastern Pacific.

Fifty nine species (34.91%) were classified as marine stragglers (MS), 51 (30,17%) as marine migrants (MM), 19 (11,24%) as estuarine (ES), and five species (2,95%) as amphidromous. Each of the other functional groups (anadromous, catadromous, estuarine migrant, estuarine resident, freshwater migrant and semi-catadromous) accounted for less than 2%. Twenty-nine species (17,15%) did not fit in any category due to the lack of information available in the literature (Table 1).

Regarding the trophic functional groups, seventy seven species (45,56%) were classified as zoobentivorous, twenty-seven species (15,97%) as piscivorous, sixteen (9,46%) as zooplanktivore, and sixteen (9,46%) as piscivorous and zoobenthivore. Each of the other trophic functional groups (detritivores, herbivores, opportunists and omnivores) accounted for less than 3%. Twenty one species (12,42%) did not fall into any category due to lack of information in the literature. Concerning the type of environment each species was found, thirty-four species (20,11%) were recorded in bays, lagoons and mangroves, fifty (29.58%) only in bays, twenty (11.83%) only in lagoons, and three (1.74%) only in mangroves (Table 1).

One hundred and forty-eight species that inhabit the Island of Santa Catarina are listed in the IUCN red list (2018), representing 87.57% of all species identified. Ten species (5.78% of the total) are listed in the MMA red list (2016), and nine species are present in both lists. Of the 148 IUCN red list species, 126 are classified as least concern, nine as vulnerable, six as near threatened and seven with deficient data. Of the ten species listed in the MMA red list, *Epinephelus itajara* and *Gymnura altavela* are categorized as critically endangered, *Epinephelus marginatus*, *Epinephelus morio*, *Hyporthodus niveatus*, *Mycteroperca bonaci*, *Hippocampus reidi* and *Zapteryx brevirostris* as vulnerable, and

Table 1. Taxonomic classification of the ichthyofauna recorded on the Island of Santa Catarina, Brazil. Geographic Distribution: CT = Circumtropical; TA = Transatlantic; WA = Western Atlantic; SWA = Southwestern Atlantic; SSWA = Southern Southwestern Atlantic; Ca = Caribbean; Br = Brazilian Province; EP = Eastern Pacific. Estuarine use and functional groups (EUFG): MS = marine stragglers; MM = marine migrants; ES = estuarine species; AN = anadromous; AM = amphidromous; FM = freshwater migrants. Trophic functional groups (TFG): ZP = zooplanktivore; DV = detritivore; HV = herbivore; OV = omnivore; PV = piscivore; ZB = zoobenthivore; OP = opportunist. Conservation status according to the international list proposed by IUCN (2018), Brazilian red list proposed by MMA (2016) and to regional list proposed by CONSEMA (2011): †† = overexploited; § = vulnerable; ‡ = near threatened; • = critically endangered; † = endangered; * = least concern; # = data deficient.

List of Species	Geographic Range	Bays	Lagoons	Mangroove	EUFG	TFG	Voucher number
Actinopterygii							
Acanthuriformes							
Sciaenidae							
Bairdiella ronchus (Cuvier, 1830)*	Ca+Br	x		x	MM	PV	SCIA 2010.001.PIS 493
Ctenosciaena gracilicirrhus (Metzelaar, 1919)*	Ca+Br	x			MS	ZB	SCIA 1982.025.PIS517
Cynoscion guatucupa (Cuvier 1830)	SSWA	x			MS	ZB	SCIA 1983.056.PIS548
Cynoscion jamaicensis (Vaillant & Bocourt, 1883)*	Ca+SWA	x		x	MM	PV/ZB	SCIA 1983.038.PIS530
Cynoscion leiarchus (Cuvier, 1830)*	Ca+Br	x		x	MS	PV	SCIA 1988.089.PIS581
Cynoscion microlepidotus (Cuvier, 1830)*	Br	x		x	MS		SCIA 1998.104.PIS596
Isopisthus parvipinnis (Cuvier, 1830)*	Ca+Br	x		x	MM	ZB	SCIA 2011.132.PIS624
Larimus breviceps Cuvier, 1830*	Ca+Br	x			MS	ZB	SCIA 2011.133.PIS625
Macrodon ancylodon (Bloch & Schneider, 1801)*	Ca+Br	x			MM	PV/ZB	SCIA 1984.064.PIS556
Menticirrhus americanus (Linnaeus, 1758)*	WA	x		x	MM	ZB	SCIA 1999.110.PIS602
Menticirrhus littoralis (Holbrook, 1847)*	WA	x	x		MS	ZB	SCIA 1991.100.PIS592
Micropogonias furnieri (Desmarest, 1823) ††/*	Ca+SWA	x	x	x	MM	ZB	SCIA 1988.084.PIS576
Odontoscion dentex (Cuvier, 1830)*	WA	x				ZB	
Paralonchurus brasiliensis (Steindachner, 1875)*	Ca+SWA	x	x		MS	ZB	SCIA 1986.073.PIS565
Pogonias cromis (Linnaeus, 1766)*/†	WA	x		x	MS	ZB	SCIA 1999.108.PIS600
Stellifer brasiliensis (Schultz, 1945)	Br	x			MM		SCIA 1982.007.PIS499
Stellifer rastrifer (Jordan, 1889)*	Br+SSWA	x	x	x	MM	ZB	SCIA 1984.066.PIS558
Stellifer stellifer (Bloch, 1790)#	Br	x			MS		
Umbrina canosai Berg, 1895 ††	SSWA	x			MS	ZB	SCIA 2003.131.PIS623
Umbrina coroides Cuvier, 1830*	WA	x	x		MS	ZB	SCIA 1988.091.PIS583
Anabantiformes							
Polynemidae							
Polydactylus virginicus (Linnaeus, 1758)*	WA	x			MM	ZB	POLY 2011.001.1218
Anguilliformes							
Muraenidae							
Gymnothorax ocellatus Agassiz, 1831*	Ca+SWA	x			ES	ZB	MURAE 2010.004.1202
Ophichthidae							
Ophichthus cylindroideus (Ranzani, 1839)*	WA	x					OPHIC 1980.003.1127
Ophichthus gomesii (Castelnau, 1855)*	WA	x	x	x	MS		OPHIC 1986.004.1128
Atheriniformes							
Atherinopsidae							
Atherinella brasiliensis (Quoy & Gaimard, 1825)*	Ca+Br	x	x	x	ES	OP	ATHE 1987.009.644
Odontesthes argentinensis (Valenciennes, 1835)	SSWA	x	x				ATHE 2011.075.1135
Aulopiformes							
Synodontidae							
Synodus foetens (Linnaeus, 1766)*	WA	x	x	x	MS	PV	SYNO 1988. 004.481
Batrachoidiformes							
Batrachoididae							
Porichthys porosissimus (Cuvier,1829)	SSWA	x			MM	ZB	BATRA 1984.009.109

Continuation Table 1.

List of Species	Geographic Range	Bays	Lagoons	Mangroove	EUFG	TFG	Voucher number
Beloniformes							
Belonidae							
Strongylura marina (Walbaum, 1792)*	WA	x	x	x	MM	PV	BELO 1988.001.128
Strongylura timucu (Walbaum, 1792)*	WA			x	MM	PV	BELO 1989.008.135
Hemiramphidae							
Hemiramphus brasiliensis (Linnaeus, 1758)*	TA		x		MM	PV/ZB	HEMI 1988.004.1170
Hyporhamphus unifasciatus (Ranzani, 1841)*	WA+EP	x	x		MS	OV	HEMI 1986.001.1167
Blenniiformes							
Blenniidae							
Hypleurochilus fissicornis (Quoy e Gaimard, 1824)*	TA		x			ZB	BLEN 1984.002.121
Parablennius pilicornis (Cuvier, 1829)*	TA		x	x	MS	ZB	BLEN 1989.004.123
Scartella cristata (Linnaeus, 1758) *	TA		x			HV	BLEN 1979.001.120
Labrisomidae							
Labrisomus nuchipinnis (Quoy & Gaimard, 1824)*	TA	x				ZB	LABRI 1994.001.1166
Carangiformes							
Carangidae							
Caranx hippos (Linnaeus, 1766)*	TA		x	x	MS	PV	CARA 1984.012.416
Caranx latus Agassiz, 1829*	TA	x	x		MM	ZB	CARA 1989.051.455
Chloroscombrus chrysurus (Linnaeus,1766)*	TA	x			MS	OP	CARA 1980.002.406
Hemicaranx amblyrhynchus (Cuvier, 1833)*	WA	x			MM	ZB	CARA 2005.079.715
Oligoplites palometa (Cuvier, 1832)*	Ca+Br	x	x	x	MM	PV	CARA 1986.024.428
Oligoplites saliens (Bloch, 1793)*	Ca+SWA	x		x	MM	ZP	CARA 1988.033.437
Oligoplites saurus (Bloch e Schneider, 1801)*	WA	x	x	x	MM	PV	CARA 2005.072.476
Selene setapinnis (Mitchill, 1815)*	WA	x			MM	PV	CARA 2003.073.477
Selene vomer (Linnaeus, 1758)*	WA	x	x	x	MM	ZB	CARA 1984.016.420
Trachinotus carolinus (Linnaeus, 1766)*	WA	x	x		MS	ZB	CARA 2005.077.713
Trachinotus falcatus (Linnaeus, 1758)*	WA	x	x		MS	ZB	CARA 1988.045.449
Trachinotus marginatus Cuvier, 1832*	SSWA		x		MS		CARA 1989.056.460
Trachurus lathami Nichols, 1920*	WA	x				PV/ZB	CARA 2003.070.474
Uraspis secunda (Poey, 1860)*	CT			x	MS		CARA 1986.027.431
Clupeiformes							
Clupeidae							
Brevoortia pectinata (Jenyns, 1842)*	SWA		x		ES	ZP	CLUP 1988.025.812
Harengula clupeola (Cuvier, 1829)*	WA	x	x	x	MS	ZP	CLUP 1999.038.825
Opisthonema oglinum (Lesueur,1818)*	WA	x	x	x	MS	ZP	CLUP 1988.024.811
Platanichthys platana (Regan, 1917)*	SSWA	x	x		ES	ZP	CLUP 1998.035.822
Sardinella brasiliensis (Steindachner, 1879) ††/ #	SSWA	x	x	x	MM	ZP	CLUP 1987.020.807
Engraulidae							
Anchoa filifera (Fowler, 1915)*	Ca+Br	x			ES		ENGR 1982.016.857
Anchoa januaria (Steindachner, 1879)*	Br	x	x	x	ES	OP	ENGR 1988.049.890
Anchoa lyolepis (Evermann & Marsh, 1900)	WA	x	x		MS	ZP	ENGR 1989.062.903
Anchoa marinii Hildebrand, 1943*	SSWA	x		x	MM	ZP	
Anchoa spinifer (Valenciennes, 1848)*	Ca+Br+EP	x			ES	PV/ZB	ENGR 1984.031.872
Anchoa tricolor (Spix & Agassiz, 1829)*	SWA	x	x		MM	ZP	ENGR 1988.048.889
Anchovia clupeoides (Swainson, 1839)*	Ca+Br	x		x	MM	ZP	
Anchoviella lepidentostole (Fowler, 1911)*	Ca+Br+EP	x			ES	PV/ZB	ENGR 1984.031.872
Cetengraulis edentulus (Cuvier, 1829)*	Ca+Br	x	x	x	MM	ZP	ENGR 1999.080.921

Continuation Table 1.

List of Species	Geographic Range	Bays	Lagoons	Mangroove	EUFG	TFG	Voucher number
Engraulis anchoita Hubbs & Marini, 1935‡	SSWA	x	x		MS	ZP	ENGR 2002.082.923
Lycengraulis grossidens (Spix & Agassiz, 1829)*	Br+SWA	x	x	x	A N	PV	ENGR 1988.051.892
Pristigasteridae							
Chirocentrodon bleekerianus (Poey, 1867)*	Ca+Br	x	x		MS	PV	CLUP 1984.016.803
Pellona harroweri (Fowler, 1917)*	Ca+Br	x	x		MS	PV	PRIST 1982.005.834
Elopiformes							
Elopidae							
Albula vulpes (Linnaeus, 1758) ‡	WA	x			AM	ZB	ELOP 1990.003.394
Elops saurus Linnaeus, 1766*	WA	x	x	x	AM	PV	ELOP 1988.002.393
Gadiformes							
Bregmacerotidae							
Bregmaceros atlanticus Goode & Bean, 1886 *	CT		x		MM	ZP	BREG 1988.001.386
Phycidae							
Urophycis brasiliensis (Kaup, 1858)	SSWA	x				ZB	PHYCI 1983.004.1116
Gobiesociformes							
Gobiesocidae							
Gobiesox barbatulus Starks, 1913*	WA	x			ES		GOBIE 1993.001.1111
Gobiiformes							
Gobiidae							
Awaous tajasica (Lichtenstein, 1822)	WA		x		AM	ZB	GOBI 1984.012.1044
Bathygobius soporator (Valenciennes, 1837)*	TA		x	x	MM	ZB	GOBI 1986.019.1051
Ctenogobius boleosoma (Jordan & Gilbert, 1882)*	WA		x		AM	ZB	GOBI 1988.028.1060
Ctenogobius shufeldti (Jordan & Eigenmann, 1887)*	WA		x		ER	OP	GOBI 1983.007.1039
Ctenogobius stigmaticus (Poey, 1860)*	WA		x		ES	ZB	GOBI 1988.036.1068
Gobionellus oceanicus (Pallas, 1770)*	WA	x	x	x	ES	ZB	GOBI 1988.033.1065
Microgobius meeki Evermann & Marsh, 1899*	Ca+Br	x			MS	ZB	GOBI 1982.002.1034
Parrella macropteryx Ginsburg, 1939*	WA	x				DV	GOBI 1984.008.1040
Pomacentridae							
Abudefduf saxatilis (Linnaeus, 1758 *	TA		x			ZB	POMAC 1991.001.1112
Istiophoriformes							
Sphyraenidae							
Sphyraena guachancho Cuvier, 1829*	TA	x		x	ES	PV	SPHYR 1983.001.1165
Lophiiformes							
Ogcocephalidae							
Ogcocephalus vespertilio (Linnaeus, 1758)	Ca+SWA	x				ZB	OGCOC 1990.001.1276
Moroniformes							
Ephippidae							
Chaetodipterus faber (Broussonet,1782)*	WA	x		x	MS	HV	EPHI 1988.006.401
Mugiliformes							
Mugilidae							
Mugil curema Valenciennes, 1836*	TA+EP	x	x	x	MM	DV	MUGI 1986.001.716
Mugil liza Valenciennes, 1836 ††/#	WA	x	x	x	CA	DV	MUGI 1987.010.725
Mugil sp Desmarest, 1831			x	x	MM		MUGI 1989.023.738
Perciformes							
Centropomidae							
Centropomus parallelus Poey, 1860*	WA	x	x	x	SC	ZB	CENT 1987.002.141

Continuation Table 1.

List of Species	Geographic Range	Bays	Lagoons	Mangroove	EUFG	TFG	Voucher number
Centropomus undecimalis (Bloch, 1792)*	WA			x	SC	PV	CENT 1998.018.157
Epinephelidae							
Epinephelus itajara (Lichtenstein, 1822) ††/§/•/†	WA	x			MM	ZB	
Epinephelus marginatus (Lowe, 1834) §	TA	x	x		MM	PV	SERRA 1986.004.1286
Epinephelus morio (Valenciennes, 1828) §	TA	x			MM	PV/ZB	
Hyporthodus niveatus (Valenciennes, 1828) §	WA	x	x		MM	PV/ZB	SERRA 1988.005.1287
Mycteroperca acutirostris (Valenciennes, 1828)*	TA	x	x		MS	ZB	SERRA 1992.009.1291
Mycteroperca bonaci (Poey, 1860) ††/‡/§	WA	x			MS	PV	
Mycteroperca microlepis (Goode & Bean,1879) §	WA	x			MM	PV/ZB	
Rypticus randalli Courtenay, 1967*	Ca+Br	x			MS		
Gerreidae							
Diapterus auratus Ranzani, 1842*	WA	x		x	EM	ZB	GERRE 2010.065.1031
Diapterus rhombeus (Cuvier, 1829)*	Ca+Br	x	x	x	MS	ZB	GERRE 1997.041.1007
Eucinostomus argenteus Baird & Girard, 1855*	WA+EP	x	x	x	MM	OV	GERRE 1988.024.990
Eucinostomus gula (Quoy & Gaimard, 1824)*	WA	x	x	x	MM	ZB	GERRE 1987.019.985
Eucinostomus lefroyi (Goode, 1874)*	Ca+Br		x	x	ES	ZP	GERRE 1988.032.998
Eucinostomus melanopterus (Bleeker, 1863)*	TA	x	x	x	MM	ZB	GERRE 1986.010.976
Eugerres brasilianus (Cuvier, 1830)*	WA		x	x	MS	ZB	GERRE 1984.008. 974
Haemulidae							
Anisotremus surinamensis (Bloch, 1791)#	WA	x	x		MS	ZB	HAEMU. 1993.017.1156
Conodon nobilis (Linnaeus, 1758)*	WA	x			MM	ZB	HAEMU. 1983.002.1141
Genyatremus luteus (Bloch, 1790)#	Ca+Br			x	MS	ZB	
Haemulon aurolineatum Cuvier, 1830*	WA		x			ZB	HAEMU. 1984.004.1143
Haemulon steindachneri (Jordan & Gilbert, 1882)*	Ca+SWA		x		MS	ZB	HAEMU. 1989.013.1152
Orthopristis ruber (Cuvier, 1830)*	Ca+SWA	x	x	x	MS		HAEMU. 1988.006.1145
Pomadasys corvinaeformis (Steindachner, 1868)*	Ca+SWA	x			MM	PV/ZB	HAEMU. 2010.024.1163
Lutjanidae							
Lutjanus analis (Cuvier, 1828) ††/‡	WA	x	x		MM	PV	LUTJA 1989.002.1178
Lutjanus jocu (Bloch & Schneider, 1801)#	WA		x		MM	PV/ZB	LUTJA 1987.001.1177
Pomatomidae							
Pomatomus saltatrix (Linnaeus,1766) ††/§	CT	x	x	x	MS	PV	POMA 1988.014.1097
Priacanthidae							
Cookeolus japonicus (Cuvier, 1829)*	CT	x				ZB	PRIAC 2005.002.1174
Heteropriacanthus cruentatus (Lacepède, 1801)*	CT	x				ZB	PRIAC 2011.004.1176
Priacanthus arenatus Cuvier, 1829*	TA+EP	x				PV/ZB	PRIAC 1983.001.1173
Serranidae							
Diplectrum formosum (Linnaeus, 1766)*	WA		x			PV/ZB	SERRA 1986.003.1285
Diplectrum radiale (Quoy & Gaimard, 1824)*	WA	x		x	MS	PV	SERRA 1982.001.1283
Pleuronectiformes							
Achiridae							
Achirus declivis Chabanaud, 1940*	WA	x			MS	ZB	ACHI 2005.022.190
Achirus lineatus (Linnaeus, 1758)*	WA	x	x	x	ES	ZB	ACHI 2010.026.296
Catathyridium garmani (Jordan, 1889)	SSWA	x			AM		
Gymnachirus nudus Kaup, 1858*	WA	x	x				ACHI 2003.016.184
Trinectes paulistanus (Miranda Ribeiro, 1915)*	Ca+Br	x			MS	ZB	ACHI 2011.024.294
Cynoglossidae							
Symphurus tessellatus (Quoy & Gaimard,1824)*	Ca+Br+SSWA	x	x	x	MM	ZB	CYNO 1998.033.329

Continuation Table 1.

List of Species	Geographic Range	Bays	Lagoons	Mangroove	EUFG	TFG	Voucher number
Paralichthyidae							
Citharichthys arenaceus Evermann & Marsh, 1900*	WA			x	MS	ZB	PARA 1988.017. PIS 943
Citharichthys macrops Dresel,1885*	WA	x		x	MS	ZB	PARA 2002.036. PIS 962
Citharichthys spilopterus Günter, 1862*	WA	x	x	x	ES	ZB	PARA 1982.003. PIS 929
Etropus crossotus Jordan & Gilbert, 1882*	WA+EP	x		x	MM	ZB	PARA 1983.010. PIS 936
Paralichthys brasiliensis (Ranzani, 1842)	SWA	x			MS		
Paralichthys orbignyanus (Valenciennes, 1839)	SSWA	x			MM	ZB	
Paralichthys patagonicus Jordan, 1889	SSWA+EP	x				PV	PARA 2002.040. PIS 966
Pleuronectidae							
Oncopterus darwinii Steindachner,1874	SSWA	x			MS	ZB	PLEUR. 2012.001.925
Scombriformes							
Gempylidae							
Thyrsitops lepidopoides (Cuvier, 1832)	WA+EP		x			PV	GEMP 1993.001.404
Scombridae							
Scomberomorus brasiliensis (Colete, Russo & Zavalla-Camim, 1978) *	Ca+Br	x		x	MS	PV	SCOMB 2011.001.1194
Trichiuridae							
Trichiurus lepturus Linnaeus, 1758*	CT	x		x	MS	PV	TRICH 2012.013.1217
Scorpaeniformes							
Scorpaenidae							
Scorpaena isthmensis Meek & Hildebrand, 1928*	WA	x			MS		SCORP 1982.001.1136
Scorpaena plumieri Bloch, 1789*	WA	x	x			PV/ZB	SCORP 1987.002.1137
Triglidae							
Prionotus nudigula Ginsburg, 1950	SSWA	x			MS	PV	TRIGL 2010.024.1275
Prionotus punctatus (Bloch, 1793)*	Ca+SWA	x	x	x	MS	ZB	TRIGL 1989.017.1268
Siluriformes							
Ariidae							
Cathorops spixii (Agassiz, 1829)	Ca+Br	X		x	ES	ZB	ARII 1987.025.215
Genidens barbus (Lacepéde, 1803) ††/†	SSWA	x		x	MM		ARII 1999.098.288
Genidens genidens (Cuvier, 1829)*	SSWA	x	x	x	MM	ZB	ARII 1987.024.214
Spariformes							
Lobotidae							
Lobotes surinamensis (Bloch, 1790)*	CT		x		MS	ZB	
Sparidae							
Archosargus rhomboidalis (Linnaeus, 1758)*	WA	x	x	x	MS	ZB	SPAR 1989.012.774
Diplodus argenteus (Valenciennes, 1830)*	SWA	x	x		MM	ZB	SPAR 1988.006.768
Syngnathiformes							
Dactylopteridae							
Dactylopterus volitans (Linnaeus, 1758)*	TA	x	x	x	MS	ZB	DACT 1989.003.390
Fistulariidae							
Fistularia tabacaria Linnaeus,1758*	TA		x		MM	PV	FISTU 1993.001.787
Syngnathidae							
Hippocampus reidi Ginsburg, 1933 ††/‡//§	WA	x	x		MM	ZP	SYNG 1992.003.490
Syngnathus folletti Herald, 1942*	SWA	x	x		MS		SYNG 1989.002.489
Tetraodontiformes							
Balistidae							
Balistes capriscus Gmelin, 1789§	TA		x				BALI 1981.002.1186

Continuation Table 1.

List of Species	Geographic Range	Bays	Lagoons	Mangroove	EUFG	TFG	Voucher number
Diodontidae							
Chilomycterus schoepfii (Walbaum, 1792) *	WA	x	x		ES	ZB	DIOD 2011.008.1110
Chilomycterus spinosus spinosus (Linnaeus, 1758)	SWA	x		x	MM	ZB	DIOD 1999.002.1104
Monacanthidae							
Aluterus schoepfii (Walbaum, 1792)*	TA		x			HV	MONA. 1988.002.1188
Monacanthus ciliatus (Mitchill, 1818)*	TA		x			HV	MONA. 1992.006.1192
Stephanolepis hispidus (Linnaeus, 1766)*	TA	x	x		MS	ZB	MONA. 1987.001.1187
Ostraciidae							
Lactophrys trigonus (Linnaeus, 1758)*	WA	x				ZB	OSTRA 2001.001.1124
Tetraodontidae							
Lagocephalus laevigatus (Linnaeus, 1766)*	WA	x	x	x	MM	PV/ZB	TETRA 1991.019.1238
Sphoeroides greeleyi Gilbert, 1900*	Ca+Br	x		x	ES	ZB	TETRA 2011.032.1251
Sphoeroides pachygaster (Müller & Troschel, 1848)*	CT	x				ZB	
Sphoeroides spengleri (Bloch, 1785)*	TA	x	x	x		ZB	TETRA 2010.031.1250
Sphoeroides testudineus (Linnaeus, 1758)*	WA	x	x	x	ES	ZB	TETRA 1998.024.1243
Sphoeroides tyleri Shipp, 1972	Br	x				ZB	TETRA 2004.028.1247
Trachiniformes							
Uranoscopidae							
Astrocopus y-graecum (Cuvier, 1829)	WA	x			MS	PV	URANO 2012.001.1203
Chondrichthyes							
Myliobatiformes							
Gymnuridae							
Gymnura altavela (Linnaeus, 1758) §/•	TA	x				PV/ZB	
Pristiformes							
Rhinobatidae							
Pseudobatos percellens (Walbaum, 1792) ‡	TA	x			MS	ZB	RHINO 2005.002.1279
Zapteryx brevirostris (Muller & Henle, 1841) §	SWA	x					RHINO 2005.003.1280
Torpediniformes							
Narcinidae							
Narcine brasiliensis (Olfers, 1831)#	WA		x		MS	ZB	NARCI 1991.001.1277

Pogonias cromis and *Genidens barbus* as endangered. Only two species (*Epinephelus itajara* – endangered; *Hippocampus reidi* – vulnerable) are listed in the regional extinction list (CONSEMA, 2011) (Table 1).

Discussion

In Western Atlantic estuaries, Sciaenidae, Engraulidae, Ariidae and Gerreidae are among the seven most representative families in abundance in bottom trawling (Vieira & Musick 1994). Members of the families Sciaenidae and Engraulidae possess a wide tolerance to variations in salinity and temperature, which favors their occurrence in both estuarine and coastal waters along the Atlantic coast of South America (Camargo & Isaac 2003). The total species richness reported for the Island of Santa Catarina was relatively high when compared to other areas, such as Guaratuba Bay (southern coast of Paraná) (87 spp.; Chaves & Corrêa 1998, Chaves & Vendel 2001) and Babitonga Bay (northern coast of Santa Catarina) (150 spp.; Vilar et al. 2011). These differences may have arisen because of differences in area among sites (Guaratuba Bay- 48 km^2, Babitonga Bay-130 km^2 , Island of Santa Catarina- 431 km^2) and/or because of the higher sampling effort in our study area (in number of samplings and variety of environments).

In terms of number of species, the total species richness of the Island of Santa Catarina is relatively higher than that of most of the coastal areas from the Western Atlantic [Paranaguá Estuarine Complex, southern Brazil (213 spp.; Passos et al. 2012); Guaratuba Bay, southern Brazil (87 spp.; Chaves & Corrêa 1998, Chaves & Vendel 2001); Rio da Prata estuary, northern Argentina (60 spp.; Jaureguizar et al. 2004); Caeté River estuary, northern Brazil (120 spp.; Marceniuk et al. 2017); Sergipe River estuary (136 spp.; Alcântara 2006); Curuçá estuary (98 spp.; Hercos 2006, Giarrizzo & Krumme 2007, Sarpedonti et al. 2008); Babitonga Bay (152 spp.; Vilar et al. 2011); Mataripe estuary (36 spp.; Dias et al. 2011); Paraguaçu River estuary (124 spp.; Reis-Filho et al. 2010), estuaries of northern Espírito Santo (57 spp.; Hostim-Silva et al. 2013)], and other tropical areas (number of species varying from 81 to 197; Blaber 2002), including estuaries of the biogeographic zones of the Indo-Pacific. Differences in species richness and composition may be difficult to explain since multiple specific factors can drive fish assemblage patterns, such as habitat diversity, rainfall patterns and hydrographic and oceanographic patterns. These factors act at distinct intensities and scales, leading to differences in fauna composition and richness between areas. However, these differences may be a result of insufficient sampling in the contrasting environments and/or the use of distinct fishing gear in tropical areas around the world (Blaber 2002).

The majority of the species are widely distributed in the Western Atlantic, but the segregation of species into two groups with distinct distribution is also evident. One includes species that occur in the Caribbean and in the Brazilian Province, and have affinities with the Caribbean fauna. The other, which encompasses species that occur in the Southwestern Atlantic, possesses temperate affinities and species similar to those that occur in Argentina and Uruguay.

This study provides a checklist of fish species from the Island of Santa Catarina based on a robust dataset constructed over the last 30 years. Once this study considered the diverse environments of the island (bays, lagoons and mangroves), it increased, therefore, the detectability of the species from this region. The ichthyofauna of the Island of Santa Catarina is composed by species with affinities with the tropical fauna of the Brazilian coast and the temperate fauna from Argentina and Uruguay. The species richness of the study area is relatively high when compared to other areas from Western Atlantic, emphasizing the importance of this region for the conservation of the aquatic biodiversity. In addition, some of the species reported in this study are listed in inventories of conservation status. Thus, it is suggested the monitoring of this fauna and more regional samplings for gathering more information about fish species from the Island of Santa Catarina (including the invasive species), mainly for conservation and management proposals.

Author Contributions

Gisela Costa Ribeiro: Contribution to data collection.

André Pereira Cattani: Contribution to data analysis and interpretation; Contribution to manuscript preparation.

Mauricio Hostim-Silva: Contribution to data collection.

Leandro Clezar: Contribution to data collection.

Ana Carolina dos Passos: Substantial contribution in the concept and design of the study; Contribution to manuscript preparation.

Marcelo Soeth: Substantial contribution in the concept and design of the study; Contribution to critical revision, adding intelectual content.

Olímpio Rafael Cardoso: Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Henry Louis Spach: Substantial contribution in the concept and design of the study; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Erratum: Ichthyofauna marine of the Island of Santa Catarina, Southern Brazil: checklist with comments on the species

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Article

Myriapods (Arthropoda, Myriapoda) in the Pantanal of Poconé, Mato Grosso, Brazil

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Abstract: The Brazilian Pantanal biome is one of the largest and most important floodplains in the world by virtue of its biodiversity and indispensable ecological services on local, regional, and global scales. Despite this importance, many gaps remain concerning its biodiversity as well as its generation and maintenance mechanisms. In view of expanding the information about its biological diversity, we compiled a list of Myriapoda (Arthropoda) species occurring in the Pantanal of Poconé, Mato Grosso, Brazil, based on the records from literature and on the specimens available in the zoological collections of Federal University of Mato Grosso -UFMT. A total of 33 Myriapoda species were recorded in the region. The Diplopoda species (20 spp.; 60.6%) are distributed ‘between four orders: Polydesmida, represented by five families (Chelodesmidae, notably, with three species; Paradoxosomatidae and Pyrgodesmidae, with two species each; and Cyrtodesmidae and Fuhrmannodesmidae, with one species each, recently recorded in the region); Spirostreptida, represented by Spirostreptidae, with eight species; Spirobolida, with two species (one Rhinocricidae and one not identified); and Polyxenida. The Chilopoda (10 spp.; 30.3%) belong to three orders: Scolopendromorpha, with four species of the family Scolopendridae, two Scolopocryptopidae species, and one Cryptopidae species; Geophilomorpha, with the families Aphilodontidae and Schendylidae, with one species each; and Lithobiomorpha, with one Henicopidae species. Symphyla was represented by only two species (6.1%) of the family Scutigerellidae; and Pauropoda (3.0%) by a single species of Pauropodidae. The Myriapoda species richness, as well as the high number of new records in recent studies reinforce the importance of the northern region of the Pantanal biome as a diversity center with potential priority for measures aimed at the conservation of its many habitats.

Keywords: *Biodiversity, Chilopoda, Diplopoda, Pauropoda, Symphyla.*

Miriápodes (Arthropoda, Myriapoda) do Pantanal de Poconé, Mato Grosso, Brasil

Resumo: O Pantanal de Mato Grosso é uma das maiores e mais importantes planícies de inundação do mundo, em relação à sua biodiversidade e aos seus indispensáveis serviços ecológicos em escalas locais, regionais e globais. Apesar dessa importância, existem, ainda, muitas lacunas sobre o conhecimento de sua biodiversidade, bem como de seus mecanismos geradores e mantenedores. Desse modo, a fim de contribuir com o conhecimento de sua diversidade biológica compilamos, com base na literatura e em espécimes disponíveis nas coleções e acervos zoológicos da Universidade Federal de Mato Grosso-UFMT, uma lista de espécies de miriápodes (Arthropoda, Myriapoda) ocorrentes no Pantanal de Poconé, Mato Grosso, Brasil. Um total de 33 espécies de Myriapoda foi registrado como ocorrentes nessa região. As espécies de Diplopoda (20 spp.; 60,6%), estão distribuídas em quatro ordens. Polydesmida está representada por cinco famílias, com destaque para Chelodesmidae com três espécies, Paradoxosomatidae e Pyrgodesmidae, com duas espécies cada, além de Cyrtodesmidae e Fuhrmannodesmidae, com uma espécie cada, recentemente registradas para essa região; Spirostrepida representada por Spirostreptidae, com oito espécies; Spirobolida, com duas espécies (uma Rhinocricidae e uma não identificada); e Polyxenida. Os Chilopoda (10 spp.; 30,3%) estão distribuídos em três ordens: Scolopendromorpha, com quatro espécies da família Scolopendridae, duas espécies de Scolopocryptopidae e uma espécie de Cryptopidae; Geophilomorpha, com as famílias Aphilodontidae e Schendylidae, com uma espécie cada; e Lithobiomorpha, com uma única espécie de Henicopidae. Symphyla foi representada por apenas duas espécies (6,1%) da família Scutigerellidae e Pauropoda (3,0%) por uma única espécie de Pauropodidae. A riqueza de espécies de Myriapoda, bem como a alta proporção de novos registros em estudos recentes, reforçam a importância da região norte do Pantanal como um centro de diversidade com potencial prioridade às medidas de conservação de seus variados habitats.

Palavras-chave: *Biodiversidade, Chilopoda, Diplopoda, Pauropoda, Symphyla.*

Introduction

Wetlands are defined as ecosystems inserted at the interface between terrestrial and aquatic, continental and coastal, natural or artificial environments which may permanently or periodically be flooded by shallow, fresh, briny, or salt water (Junk et al. 2015). These areas provide important ecological services on both local and global scales, with functional values related mainly to the renewal of groundwater stores, storage and maintenance of increased atmospheric humidity, protection against soil erosion, water purification, organic carbon storage, and their consequent impact on climatic conditions (Denny 1994). They also feature a mosaic of seasonally flooded habitats that are home to numerous species of significant value to biodiversity (Junk et al. 2006, Nunes-da-Cunha & Junk 2015).

Brazil is a country with a vast territory that includes a large variety of wetland types and their consequent broad biodiversity (Junk et al. 2015). The 'Pantanal' biome is one of the largest wetlands in the world, encompassing an area of approximately 138,000 km^2 (Da Silva & Abdon 1998, Fantin-Cruz et al. 2010). The Pantanal is subject to a predictable monomodal flood pulse, with marked aquatic and terrestrial phases that alternate annually (Nunes-da-Cunha & Junk 2015). This floodplain has four well-defined seasonal periods: dry season, rising water, high water, and receding water (Heckman 1998). The region floods due to the lateral overflow of great rivers or lakes, precipitation, or underground water, and the flood is classified according to its amplitude, frequency, predictability and strength (Signor et al. 2010, Junk et al. 2015).

Based on the heterogeneity of landscapes and on the intensity and duration of floods, Adámoli (1982) categorized the Pantanal into 11 sub-regions. The northern Pantanal region belonging to Mato Grosso State is formed by the sub-regions of Poconé, Cáceres, and Barão de Melgaço. The Pantanal of Poconé sub-region accounts for 11% of the entire Pantanal, covering 11,945 km^2 (Signor et al. 2010). This region has a wide variety of vegetation formations such as 'murundu' fields, clean fields, mixed formations of evergreen flooded forests ('landizal') with dominance of *Calophyllum brasiliensis* Cambess (Clusiaceae) and 'cerradão', dense tree savannas (mountain ranges), in addition to monodominant dense fields of *Callisthene fasciculata* (Spr.) Mart. (Vochysiaceae) ('carvoal'), *Attalea phalerata* Mart. (Arecaceae) ('acurizal'), *Vochysia divergens* Pohl. (Vochysiaceae) ('cambarazal'), as well as aquatic and semi-aquatic vegetations (Silva et al. 2000, Santos et al. 2003, Arieira & Nunes-da-Cunha 2006, Nunes-da-Cunha et al. 2007, 2010, Nunes-da-Cunha & Junk 2015).

Although the Pantanal of Mato Grosso state is known for its importance as a wetland, many gaps exist knowledge about regarding its biodiversity and maintenance mechanisms, especially well-defined species-richness values for some groups or lists of species. This clearly demonstrates the need for more in-depth knowledge of the biology and taxonomy of the species occurring in that region (Junk et al. 2006), especially for poorly studied taxa with sparse information like Myriapoda (e.g. Golovatch et al. 2005, Junk et al. 2006, Battirola et al. 2009, 2017, Pinheiro et al. 2009, 2011, Santos-Silva et al. 2018a,b).

Myriapoda are widespread across all continents, except Antarctica, with greatest diversity concentrated in the tropical and hot temperate regions. They are widely distributed in several habitats such as soil, plant litter, tree barks and trunks, forest canopy, fields and pastures, dense forests, deserts, caverns, and coastal areas (Hopkin & Read 1992, Golovatch et al. 1995, 2005, Knysak & Martins 1999, Kime & Golovatch 2000, Scheller 2002, Scheller & Adis 2002, Edgecombe & Giribet 2007, Minelli & Golovatch 2013, Battirola et al. 2017). At present, this group consists of four taxonomic classes: Diplopoda, Chilopoda, Symphyla, and Pauropoda.

The Diplopoda correspond to a great part of the soil and plant-litter macrofauna in most terrestrial biomes, where they act on the decomposition, reduction, and fragmentation of plant litter (Hopkin & Read 1992, Golovatch et al. 1995, Hoffman et al. 2002, Battirola et al. 2011), in addition to constituting the largest group of Myriapoda, with more than 12,000 species (Sierwald & Bond 2007). The Chilopoda are important predators that control populations of other arthropods and small vertebrates. They currently comprise five orders, with approximately 3,300 species described around the world (Edgecombe & Giribet 2007). The lowest diversity taxa of myriapods comprise the Symphyla and the Pauropoda. The former corresponds to the group of Myriapoda with the lowest species richness, containing around 200 species distributed into two families and 15 genera (Scheller & Adis 2002). The Pauropoda, in turn, have 0.5 to 1.5 mm in length, with a world fauna consisting of two orders, five families, 30 genera, and around 708 species described (Scheller 2002).

These organisms are of utmost importance for the balance of systemic functions, since they act as predators and decomposers, but little research has been undertaken in the Pantanal of Mato Grosso State on the biology, taxonomy, and diversity of Myriapoda. The present study presents a compilation of information available in the literature and in different zoological collections of the Federal University of Mato Grosso on the occurrence of these taxa in the Pantanal of Poconé - MT, to expand the knowledge of the biodiversity of the Pantanal of Mato Grosso State.

Material and Methods

For the data compilation, we used Myriapoda (Diplopoda, Chilopoda, Symphyla, and Pauropoda) occurrence metadata available in the scientific literature referring to the Pantanal of Poconé region (Figure 1) as well as the results obtained in studies led by the teams of the Laboratory of Ecology and Taxonomy of Terrestrial and Aquatic Arthropods (LETA) of the Bioscience Institute at the Federal University of Mato Grosso, in Cuiabá, Mato Grosso; of the Biological Collection of Southern Amazon (ABAM) at the Federal University of Mato Grosso, in Sinop, Mato Grosso; and of the Zoological Collection of the Federal University of Mato Grosso, in Cuiabá, Mato Grosso.

In addition to the species survey, information is provided about their record location, associated vegetation types, site of deposition of the control material sampled in the region and collection method. Different sampling methodologies were used in the studies with myriapods, e.g., Winkler and mini-Winkler extractors, ground and tree photo-eclectors, pitfall traps, manual collection, and canopy fogging (Table 1). Species determined only at generic level and present in more than one habitat or record were grouped as a single taxon, in view of the difficulty in determining these individuals sampled in different studies. The Polyxenida, which were not identified at lower taxonomic levels in any of the studies for this region, were considered a single taxon.

Results

Thirty-three Myriapoda taxa were recorded in the Pantanal of Poconé, corresponding to species of Diplopoda (20 spp.; 60.6%), followed by Chilopoda (10 spp.; 30.3%), Symphyla (2 spp.; 6.1%), and Pauropoda (1 sp.; 3.0%) (Table 1).

The 20 diplopod species were distributed into four orders, the largest being Polydesmida (9 spp.; 45%) and Spirostreptida (8 spp.; 40%), followed by Spirobolida (2 spp.; 10%) and Polyxenida (1 sp.; 5%).

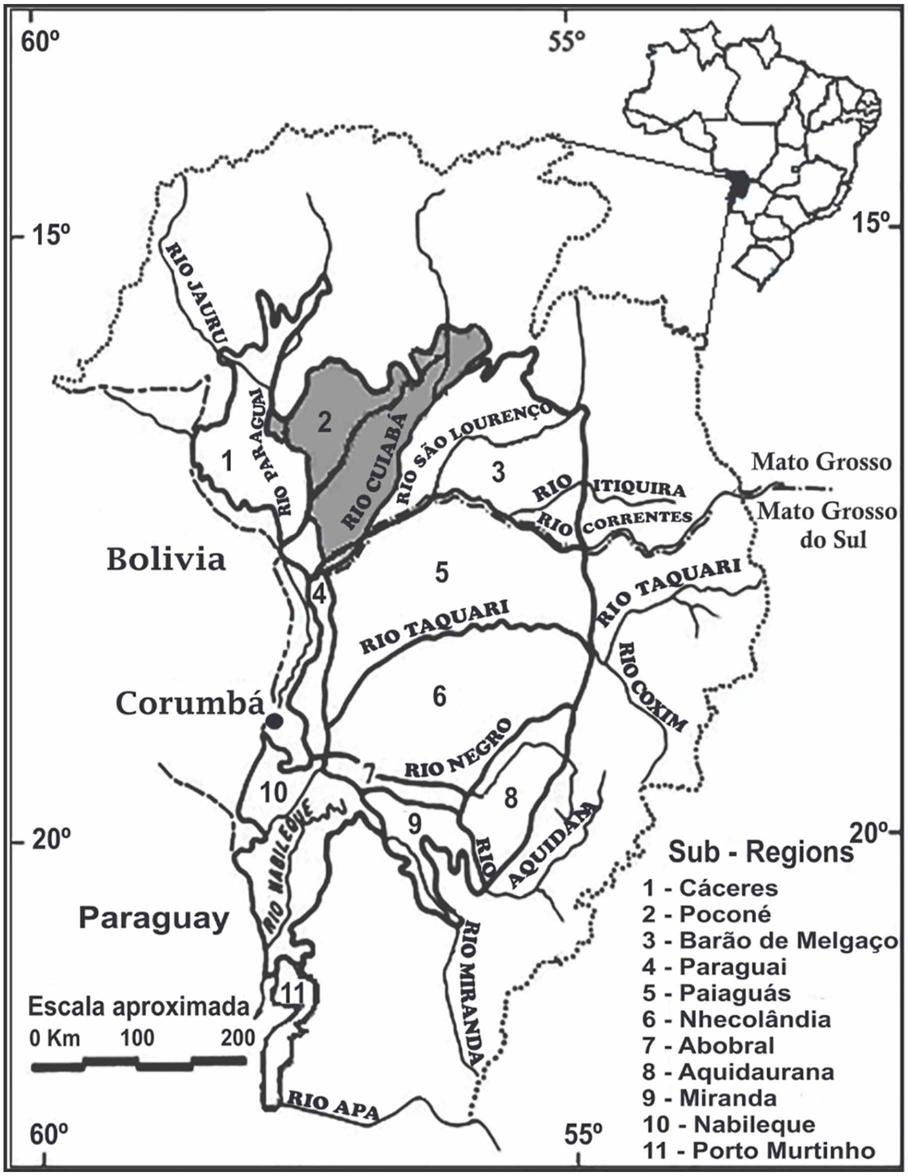

Figure 1. Map of the Pantanal and its sub-regions, between the parallels 16° and 21° S and the meridians 55° and 58° W, highlighting the Pantanal of Poconé (Modified from Silva et al., 2000).

Table 1. Data compilation of Myriapoda (Chilopoda, Diplopoda, Pauropoda, and Symphyla) species richness in the Pantanal of Poconé, Mato Grosso, Brazil. Locations: PC - Porto Cercado/Poconé-MT; PI - Pirizal/Nossa Senhora do Livramento-MT; PJ - Porto Jofre-MT; RT - Rodovia Transpantaneira/Poconé-MT; IT - Itaisi/MT; SL - Rio São Lourenço. Habitats = AC - acurizal (monodominance of *A. phalerata*); CA - cambarazal (monodominance of *V. divergens*); CO - mountain range vegetation; CM - murundum field; CV - carvoal (monodominance of *C. fasciculata*); LA - landizal (dominance of *C. brasiliensis*); CE - cerradão; CL - clean field; SV - under plant pot/land area/no sign of vegetation. Sampling method = EXW - Winkler extractor; EMW - mini-Winkler extractor; FET - tree photo-eclector; FES - soil photo-eclector; PTR - pitfall traps; CMA - manual collection; CFA - canopy fogging. Collections with control material = ABAM - Biological Collection of Southern Amazonia, Mato Grosso, Brazil; CZRAS - Zoological Collection of the Russian Academy of Science, Moscow, Russia; CZUFMT-MYR - Zoological Collection of the Federal University of Mato Grosso - Myriapoda, Mato Grosso, Brazil; FMNH - The Field Museum of Natural History, Illinois, United States; INPA - National Institute of Amazonian Research, Manaus, Brazil; LETA - Laboratory of Ecology and Taxonomy of Arthropods, Mato Grosso, Brazil; MLP - La Plata Museum, La Plata, Argentina; MNHG (Geneve) Museum of Natural History, Geneva, Switzerland, Genebra, Switzerland -; MPIL - Max-Planck Institute for Limnology, Plön, Germany; MPEG (Belem) - Museu Paraense Emílio Goeldi, Pará, Brazil; MZUSP - Zoology Museum of the University of São Paulo, São Paulo, Brazil; VMNH (Martinsville) - Virginia Museum of Natural History, Virginia, United States.

Taxa	Species	Location	Habitat	Method	Collection	Reference
Diplopoda						
Polydesmida						
Chelodesmidae	*Brasilodesmus* sp.	PC	AC, CE	EMW, PTR	ABAM	Santos-Silva et al. (2018a)
	Leiodesmus validus (Attems, 1898)	PJ	SV	-	-	Golovatch et al. (2005)
	Pantanalodesmus marinezae Hoffman, 2000	RT, PI	AC	CMA	CZUFMT-MYR FMNH, INPA, MNHG, MPEG, MZUSP, VMNH, CZRAS	Hoffman (2000) Adis et al. (2001) Golovatch et al. (2005)
Cyrtodesmidae	Cyrtodesmidae sp.	PC	AC, CE	PTR	ABAM	Santos-Silva et al. (2018a)
Fuhrmannodesmidae	Fuhrmannodesmidae sp.	PC	AC	EMW	ABAM	Santos-Silva et al. (2018a)
Paradoxosomatidae	*Catharosoma paraguayense* (Silvestri, 1895)	PJ	SV	-	-	Golovatch et al. (2005)
	Promestosoma boggianii Silvestri, 1898	PC, PI	AC, CA, CL, CM, CV, CE, LA, CO	EXW, PTR	ABAM, LETA	Battirola et al. (2009) Wantzen et al. (2016) Santos-Silva et al. (2018a,b)
Pyrgodesmidae	*Myrmecodesmus hastatus* (Schubart, 1945)	PC	SV	CMA	LETA	Pinheiro (2013)
	Poratia salvator Golovatch & Sierwald, 2001	PC, PI	CA, CL, LA, CE	CMA, EXW, EMW, PTR	ABAM, LETA	Golovatch et al. (2005) Battirola et al. (2009) Pinheiro (2013) Pinheiro et al. (2009, 2011) Wantzen et al. (2016) Santos-Silva et al. (2018a)
Polyxenida Polyxenidae	Polyxenidae sp.	PC, PI	AC, CA, CM	CAF, EXW, EMW, FES, FET, PTR	ABAM, LETA	Golovatch et al. (2005) Battirola et al. (2009, 2017) Marques et al. (2011) Santos-Silva et al. (2018a)
Spirobolida	Spirobolida sp.	PI	CA	EXW	ABAM, LETA	Battirola et al. (2009, 2017)
Rhinocricidae	*Anadenobolus* sp.	PI	SV	-	-	Golovatch et al. (2005)
Spirostreptida	Spirostreptida sp.	PI	AC	EXW	LETA	Marques et al. (2011)
Spirostreptidae	*Heteropyge paraguayensis* (Silvestri,1895)	IT	SV	-	-	Golovatch et al. (2005)
	Orthoporus (aff.) *americanus* (Silvestri, 1895)	PC, PI	CO	PTR	ABAM	Golovatch et al. (2005) Santos-Silva et al. (2018a)

Continuation Table 1.

Taxa	**Species**	**Location**	**Habitat**	**Method**	**Collection**	**Reference**
Spirostreptidae	*Plusioporus salvadorii* Silvestri, 1895	PC, PI	AC, CA, CL, CV	EXW, EMW, CMA, PTR	ABAM, LETA	Adis et al. (2001) Battirola et al. (2009, 2017) Santos-Silva et al. (2018a)
	Plusioporus sp.	PJ, SL	SV	-	-	Golovatch et al. (2005)
	Trichogonostreptus (Oreastreptus) mattogrossensis (Silvestri, 1902)	PC, IT, PI	AC, CA, CL, CM, CV, CE, CO	EXW, EMW, PTR	ABAM, LETA	Golovatch et al. (2005) Battirola et al. (2009, 2017) Santos-Silva et al. (2018a)
	Urostreptus sp.	PC, PI	CO, CA	PTR	ABAM, LETA	Golovatch et al. (2005) Battirola et al. (2009, 2017) Santos-Silva et al. (2018a)
	Urostreptus tampiitauensis (Shubart, 1947)	PC	CO	PTR	ABAM	Santos-Silva et al. (2018a)
Chilopoda						
Scolopendromorpha Cryptopidae	*Cryptops* sp.	PC	AC, CA, CO	EXW, FET, PTR	ABAM, LETA, CZUFMT-MYR	Battirola et al. (2017) Santos-Silva et al. (2018a)
Scolopocryptopidae	*Newportia (Tidops) balzanii* Silvestri, 1895	PC	AC, CO	EMW	ABAM, CZUFMT-MYR	Santos-Silva et al. (2018a)
	Newportia (Tidops) sp.	PC, PI	AC	EXW, EMW, CZUFMT-MYR	ABAM, LETA	Marques et al. (2011) Santos-Silva et al. (2018a)
Scolopendridae	*Otostigmus tidius* Chamberlin, 1914	PC	AC, CM, CV, CO	PTR	ABAM, CZUFMT-MYR	Santos-Silva et al. (2018a)
	Otostigmus sp.	PC	LA, CO	PTR	ABAM, CZUFMT-MYR	Santos-Silva et al. (2018a)
	Rhysida celeris (Humbert & Saussure, 1870)	PC, PI	CM, CV, CE, CA, CO	PTR, FET, EMW, EXW	ABAM, LETA, CZUFMT-MYR	Battirola et al. (2017) Santos-Silva et al. (2018a)
	Scolopendra viridicornis Newport, 1844	PC	CO	PTR	ABAM, CZUFMT-MYR	Santos-Silva et al. (2018a)
Geophilomorpha Aphilodontidae	*Aphilodon angustatus* Silvestri, 1909	PI	CA	CMA, CZUFMT-MYR	MLP, MZUSP	Pereira et al. (2007) Battirola et al. (2017)
Schendylidae	*Schendylops inquilinus* Pereira et al., 2007	PC, PI	AC, CA, CL, CM, CO, CV, CE	EXW, EMW, FET, CMA, PTR, CZUFMT-MYR	ABAM, LETA, MLP, MZUSP	Pereira et al. (2007) Marques et al. (2011) Battirola et al. (2017) Santos-Silva et al. (2018a)
Lithobiomorpha Henicopidae	*Lamyctes* sp.	PC, PI	AC, CA, CL, CM, CV, CE, CO	EMW, EXW, PTR, CZUFMT-MYR	ABAM, LETA	Battirola et al. (2017) Santos-Silva et al. (2018a)
Symphyla						
Scutigerellidae	*Hanseniella guimaraensis* Scheller, 2007	PI	CA	FES, EW	MNHG, MZUSP	Scheller (2007) Battirola et al. (2017)
	Hanseniella orientalis (Hansen, 1903)	PC	SV	CMA	MNHG, MZUSP	Scheller (2007)
Pauropoda						
Tetramocerata Pauropodidae	*Allopauropus (Allopauropus) pantanalicus* Scheller, 2007	PI	CA	FES	MNHG, MZUSP	Scheller (2007) Battirola et al. (2017)

Polydesmida corresponded to five families: Chelodesmidae, which stood out with three records (*Brasilodesmus* sp., *Leiodesmus validus* (Attems, 1898), and *Pantanalodesmus marinezae* Hoffman, 2000); Paradoxosomatidae, with two species (*Catharosoma paraguayense* (Silvestri, 1895) and *Promestosoma boggianii* Silvestri, 1898; Pyrgodesmidae, with *Myrmecodesmus hastatus* (Schubart, 1945) and *Poratia salvator* Golovatch & Sierwald, 2001; and Cyrtodesmidae and Fuhrmannodesmidae, with one morphospecies each (Table 1). In Spirostreptida, Spirostreptidae species predominated, notably *Heteropyge paraguayensis* (Silvestri, 1895), *Orthoporus* (aff.) *americanus* (Silvestri, 1895), *Plusioporus salvadorii* Silvestri, 1895, *Plusioporus* sp., *Trichogonostreptus* (*Oreastreptus*) *mattogrossensis* (Silvestri, 1902), *Urostreptus tampiitauensis* (Shubart, 1947), and *Urostreptus* sp. The Spirobolida were represented by two species, only: *Anadenobolus* sp. (Rhinocricidae) and Spirobolida sp. (indeterminated family) (Table 1). Lastly, Polyxenida was represented by the family Polyxenidae (Table 1).

The Chilopoda were represented by species of three orders: Scolopendromorpha (7 spp.; 70%), Geophilomorpha (2 spp.; 20%), and Lithobiomorpha (1 sp.; 10%). Noteworthy families among the Scolopendromorpha were the Scolopendridae, represented by *Otostigmus tidius* Chamberlin, 1914, *Otostigmus* sp., *Rhysida celeris* (Humbert & Saussure, 1870), and *Scolopendra viridicornis* Newport, 1844. There were also the families Cryptopidae, represented by *Cryptops* sp., and Scolopocryptopidae, represented by *Newportia* (*Tidops*) *balzanii* Silvestri, 1895 and *Newportia* (*Tidops*) sp. Among the Geophilomorpha, two families were recognized: Aphilodontidae, with the species *Aphilodon angustatus* Silvestri, 1909, and Schendylidae, with *Schendylops inquilinus* Pereira et al., 2007 (Table 1). For Lithobiomorpha, only Henicopidae were recorded, represented by *Lamyctes* sp. Symphyla was found in only two Scutigerellidae species: *Hanseniella guimaraensis* Scheller, 2007 and *Hanseniella orientalis* (Hansen, 1903), while Pauropoda was represented by only one Pauropodidae species: *Allopauropus* (*Allopauropus*) *pantanalicus* Scheller, 2007.

As for the different types of methodologies and habitats in which the studies were carried out, the highest species occurrence was recorded for the 'acurizal' (15 spp.; 18.5%), 'cambarazal' (14 spp.; 17.3%), and mountain range (14 spp.; 17.3%) areas, whereas the lowest were obtained in 'cerradão' (8 spp.; 9.9%), 'murundum' field (7 spp.; 8.6%), 'carvoal' (7 spp.; 8.6%), clean field (6 spp.; 7.4%), and 'landizal' (3 spp.; 3.7%) areas. Seven species (8.6%) cited in the literature as occurring in the Pantanal of Poconé sub-region do not have an indication of the type of habit in which they were sampled (Table 1).

Discussion

In the Pantanal of Poconé, the Myriapoda fauna has considerable species richness; however, to the present date, it has been characterized by the dominance of few taxa (Golovatch et al. 2005, Battirola et al. 2009, Pinheiro et al. 2009, 2011, Santos-Silva et al. 2018a). The majority of species corresponds to large-sized individuals, which are thus more easily collected, corroborating Golovatch et al. (2005). The same was described in recent studies on Chilopoda (Battirola et al. 2017, Santos-Silva et al. 2018a). These results can explain why the Symphyla and Pauropoda showed a lower number of species in studies conducted in that region: probably because these myriapods are small-sized, have little mobility, and are associated with the soil organic layers, their sampling is more difficult. This is especially true considering the sampling methods already used for arthropods in the region such as pitfall traps and Winkler extractors (e.g. Battirola et al. 2017, Scheller 2007), which are considered unsuitable for the sampling of Symphyla and Pauropoda (Battirola et al. 2017). Those myriapods should preferably be sampled using specific extraction methods such as soil flotation, Kempson apparatuses, and Berlese funnels (Scheller 2002, Scheller & Adis 2002).

Other surveys have shown structural differences regarding assemblages of Myriapoda in comparison with that sampled from the Pantanal of Poconé sub-region in Mato Grosso State. In Central Amazon, assemblages are mostly constituted by small-sized taxa such as Henicopidae (Chilopoda), Pyrgodesmidae, Furhmannodesmidae (Diplopoda), Pauropodinae (Pauropoda) and Scutigerellidae (Symphyla), though with elevated species richness (Adis 1997, Adis & Harvey 2000, Adis et al. 2002, Foddai et al. 2002, Hoffman et al. 2002, Scheller & Adis 2002, Scheller 2002). For the Pantanal of Poconé, Spirostreptidae, Paradoxosomatidae, and Chelodesmidae predominate among the Diplopoda, while the Scolopendridae prevail among the Chilopoda, characterizing the assemblage as containing large-sized individuals and a smaller number of species in each habitat (e.g. Golovatch et al. 2005, Scheller 2007, Battirola et al. 2017, Santos-Silva et al. 2018a). An example of such variation can be verified in the Myriapod species richness of the Ducke Reserve near the city of Manaus, Central Amazon, whose 73 species occurring in the area are divided into 31 Pauropoda, 23 Chilopoda, 14 Diplopoda, and five Symphyla (Adis et al. 2002).

Despite the remarkable difference in Myriapoda assemblage structure in Central Amazon and Pantanal of Poconé, we must stress that studies conducted in the Pantanal and its sub-regions are still very recent (Adis et al. 2001, Golovatch et al. 2005, Pereira et al. 2007, Scheller 2007, Pinheiro et al. 2009, 2011, Battirola et al. 2009, 2017, Wantzen et al. 2016, Santos-Silva et al. 2018a,b) when compared with those performed in Central Amazon (Hoffman 1984, Adis 1986, 1992, 1997, Tapia-Coral 1999, Adis & Harvey 2000, Adis et al. 2002, Foddai et al. 2002, Hoffman et al. 2002, Scheller 2002, Scheller & Adis 2002). Two other important factors are the difference in mechanisms responsible for maintaining the seasonality present in the Pantanal and in Central Amazon (e.g. Junk et al. 2015) and the distinct habitat structures of those areas. The Pantanal has sudden humidity drops throughout the year and vegetation types with prevalence of herbaceous plants on sandy soils and a consequently low nutritional content to support a diversified myriapod fauna (Golovatch et al. 2005).

The same variation is observed for Southern Amazon, which has also had its biological diversity recently investigated (Battirola et al. 2011, 2016, Noronha et al. 2015, Batistella et al. 2015). The Myriapoda fauna in the Pantanal of Poconé and Southern Amazon can be considered similar in terms of assemblage structure, given the size of its individuals, species richness, and proportion of new records, besides the short period of studies and sampling carried out in the region. Battirola et al. (2016) reported the occurrence of 20 Myriapoda species distributed into Chilopoda (7 spp.) and Diplopoda (13 spp.) in the State Park of Cristalino, Mato Grosso state. Another survey conducted in Southern Amazon, in the municipality of Cotriguaçu, Mato Grosso state, also had 20 diplopod species recorded, consisting mostly of Polydesmida (9 spp.), Spirostreptida (5 spp.), Spirobolida (5 spp.) and Polyxenida (1 sp.) (Battirola et al. 2011). Batistella et al. (2015) analyzed the distribution of three Spirostreptidae species in an Amazon area of Mato Grosso State and associated the occurrence of these species with the abiotic conditions of the habitats, evidencing the larger size of species in that region.

In the Pantanal, seasonal floods exert a limiting function on the vegetation, selecting species adapted to periodical conditions (Rebellato & Nunes-da-Cunha 2005, Arieira & Nunes-da-Cunha 2006, Machado et al. 2012) and influencing the distribution of different vegetation types in the region (Nunes-da-Cunha & Junk 2015); hence the movement of the fauna across habitats, including the Myriapoda (Battirola et al. 2009, 2017, Wantzen et al. 2016, Santos-Silva et al. 2018a,b). To tolerate the changes that take place in the habitat structure due to water seasonality, some myriapod species developed strategies to adapt to and survive in the Pantanal. The Polyxenida in this region showed a pattern of distribution between soil and tree canopies influenced by the seasonal variation of environmental conditions (Battirola et al. 2009). *Poratia salvator* and *Promestosoma boggianii* adapted their life cycle, reproduction, and phenology to the flood cycles occurring in the region (Pinheiro et al. 2009, 2011, Wantzen et al. 2016, Santos-Silva et al. 2018b), while other species developed temporary migratory strategies (Adis et al. 2001, Battirola et al. 2009, 2017).

The Myriapoda have a fundamental role in the balance of ecosystems, as they act by fragmenting organic matter — the feed base of other animals (e.g. Diplopoda, Symphyla, Pauropoda) — in addition to being important predators that help to control the population of other organisms (e.g. Chilopoda) (Hoffman et al. 2002, Edgecombe & Giribet 2007, Battirola et al. 2011, Minelli & Golovatch 2013, Noronha et al. 2015, Guizze et al. 2016). The great species richness of myriapod species, ocurrence of new records, and estimated number of species in the Pantanal (e.g. Golovatch et al. 2005, Battirola et al. 2009, Pinheiro et al. 2009, 2011, Santos-Silva et al. 2018a) reinforce the importance of the region as an area of wide diversity, with potential priority for conservation measures. It is thus paramount to acknowledge the diversity of macrohabitats in that region for the maintenance of this diversity; and to protect the structural and functional integrity of these important wetlands.

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Author Contributions

Leandro Dênis Battirola: Substantial contribution in the concept and design of the study; Contribution to manuscript preparation; Contribution to data interpretation.

Lorhaine Santos-Silva: Substantial contribution in the concept and design of the study; Contribution to manuscript preparation; Contribution to data interpretation.

Serguei Ilyich Golovatch: Contribution to critical revision, adding intellectual content.

Tamaris Gimenez Pinheiro: Contribution to critical revision, adding intellectual content.

Amazonas Chagas-Jr: Contribution to critical revision, adding intellectual content.

Marinêz Isaac Marques: Contribution to critical revision, adding intellectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

All biological material collected in the different studies evaluated in this data compilation, has the appropriate collection permits in environmental bodies.

Availability of Data and Material

All material collected from Myriapoda (Diplopoda,Chilopoda, Symphyla and Pauropoda) is duly registered and deposited in the Acervo Biológico da Amazônia Meridional - ABAM, in the zoological collections of UFMT, and others zoological collections.

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Inventory

Freshwater fishes of the Parque Nacional dos Lençóis Maranhenses and adjacent areas

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Abstract: We present here an embracing freshwater fish inventory of the Parque Nacional dos Lençóis Maranhenses and adjacent areas, reporting 49 fish species, 33 of which were identified accurately at the species level, representing ten orders and 25 fish families that range from obligate freshwater to estuarine organisms. This number of species is much larger than two previous studies for the park, each reporting just 12 and 33 fishes occurring on freshwater environments. Among the 49 freshwater species recorded in this study, 14 are new records for the Parque Nacional dos Lençóis Maranhenses, and just one corresponds to an introduced species. Some of the 14 new records in the Parque Nacional dos Lençóis Maranhenses, cited above, as well as some of the 16 species which we are not able to identify accurately at the species level, could include undescribed species, but more study is necessary before sorting out which species are truly undescribed, and which are already described ones. The orders reported by this survey which comprise the highest percentage of species richness, excluding introduced species, were: Characiformes, Cichliformes and Siluriformes, in the same ranking position, and Gymnotiformes, as expected for Neotropical freshwater surveys. The families with the highest number of species, excluding non-native species, were: Characidae, followed by Cichlidae, and Loricariidae. Out of the 33 species herein identified accurately at the species level, five of them are species typically found in brackish water environments, and when occurring on freshwater environments, are restricted mainly to estuaries, or, occasionally, the lower portions of the rivers. Thus, we will not address them in our biogeographical comments. From the remaining 28 species, eight did not occur in the Amazon River basin, six of them being endemic to the Maranhão-Piauí ecoregion. The remaining species herein reported also have their distribution recorded for the Amazon River basin, which shows the great influence of the Amazon basin. In the last two decades efforts to inventory the freshwater fish fauna and to taxonomically solve some groups occurring on the Maranhão state have been made. However the knowledge regarding the composition of the Maranhão freshwater fishes is still insufficient and underestimated, with several groups still lacking adequate taxonomic and systematic resolution, and with many gaps of knowledge, something that is not appropriate for our current picture of "biodiversity crisis". As well as, the other Brazilian protected areas, the PNLM fails to preserve its freshwater environment properly, since it includes only fragments of the major river systems of the area, not including and conserving the hole river drainages, mainly excluding their headwaters. Thus, its water bodies are exposed to typical human impacts.

Keywords: *Biodiversity, ichthyology, Periá River basin, Preguiças River basin.*

Peixes de água doce do Parque Nacional dos Lençóis Maranhenses e áreas adjacentes

Resumo: Nós apresentamos aqui um inventário de peixes de água doce do Parque Nacional dos Lençóis Maranhenses e áreas adjacentes, relatando 49 espécies de peixes, 33 dos quais foram identificados com precisão à nível de espécie, representando dez ordens e 25 famílias de peixes que variam de água doce à organismos estuarinos. Esse número de espécies é muito maior do que dois estudos anteriores para o parque, cada um registrando apenas 12 e 33 espécies de peixes ocorrendo em ambientes de água doce. Entre as 49 espécies de água doce registradas neste estudo, 14 são novos registros para o Parque Nacional dos Lençóis Maranhenses, e apenas um corresponde a uma espécie introduzida. Alguns dos 14 novos registros no Parque Nacional dos Lençóis Maranhenses, citados acima, bem como algumas das 16 espécies que não foram possíveis de serem identificadas com precisão no nível de espécie, podem incluir espécies não descritas. Entretanto, são necessários mais estudos antes de se ter certeza de quais espécies são verdadeiramente não descritas, e quais já são descritas. As ordens relatadas por esta pesquisa que compõem a maior porcentagem de riqueza de espécies, excluindo espécies introduzidas, foram: Characiformes, Cichliformes e Siluriformes na mesma posição do ranking, e Gymnotiformes, como esperado para levantamentos de água doce Neotropical. As famílias com maior número de espécies, excluindo espécies não nativas, foram: Characidae, seguida por Cichlidae e Loricariidae. Das 33 espécies aqui identificadas com precisão no nível de espécie, cinco delas são espécies tipicamente encontradas em ambientes de água salobra, e quando ocorrem em ambientes de água doce, são restritas principalmente a estuários, ou ocasionalmente, as porções mais baixas dos rios. Assim, não os abordaremos em nossos comentários biogeográficos. Das 28 espécies restantes, oito não ocorrem na bacia do rio Amazonas, sendo seis endêmicas da ecorregião Maranhão-Piauí. As espécies restantes aqui relatadas também têm sua distribuição registrada para a bacia do rio Amazonas, o que mostra sua grande influência. Nas últimas duas décadas foram feitos esforços para inventariar a fauna de peixes de água doce e resolver taxonomicamente alguns grupos que ocorrem no estado do Maranhão. No entanto, o conhecimento sobre a composição dos peixes de água doce do Maranhão ainda é insuficiente e subestimado, com vários grupos ainda sem resolução taxonômica e sistemática adequada, e com muitas lacunas de conhecimento, algo que não é apropriado para nosso quadro atual da "crise da biodiversidade". Assim como as demais áreas de proteção brasileiras, o PNLM falha em preservar seus ambientes de água doce de forma apropriada, já que ele inclui apenas fragmentos dos maiores sistemas fluviais da área, não incluindo e conservando as drenagens inteiramente, principalmente excluindo suas cabeceiras. Sendo assim, seus corpos de águas estão expostos a típicos impactos humanos.

Palavras-chave: *Biodiversidade, ictiologia, Rio Periá, Rio Preguiças.*

Introduction

South America presents a rich ichthyofauna, with an estimative of more than 9,100 valid species occurring in freshwater and marine environments of coastal areas (about 25% of all world fish species). Only for freshwater, there are about 5,100 described species; about a third of all freshwater fish species in the world (Reis et al. 2016). The published Check List of Freshwater Fish from South and Central America (CLOSSFCA) (Reis et al. 2003) listed about 4,500 valid species for the Neotropical region, also estimating that there was still at least 1,550 undescribed species. However, new estimates point that freshwater ichthyofauna diversity from the Neotropics may be even higher, with up to 8,000 or 9,000 species (Reis et al. 2016), a similar estimative proposed by Schaefer (1998). Since the publication of CLOFFSCA, an average of 104 new species have been described every year in South America, totalizing 1,142 new species. In other words, about 28% of the ichthyofauna known in South America has been described in the last 11 years, according to Reis et al. (2016).

Brazil concentrates the largest hydrographic networks of the Neotropics, which present high aquatic biodiversity, comprehending about 20% of all freshwater fish species in the world (Buckup et al. 2007). Under the conservationist lens, Brazil can be considered a nursery for aquatic biodiversity, especially when it comes to freshwater fish. In addition, Brazil comprises about 55% of freshwater fish species of the Neotropics (Reis et al. 2003, Buckup et al. 2007). Estimates predict that between 2,600 and 3,100 valid species belonging to the families that exclusively inhabit freshwater environments occur within the national territory, comparatively a much higher diversity than Brazil's marine ichthyofauna (Buckup et al. 2007, Fishbase 2019). Most of this diversity corresponds to small and medium size species, which are distributed mainly in small streams (Lowe-McConnel 1999).

Despite these attributes, the country has been suffering from severe environmental impacts caused by exploratory human activities, the degeneration and alteration of the natural habitats being the most harmful aspects in terms of conservation and consequently leading to the decline of biodiversity. Natural environments, both in Brazil and in the world, have been suffering a swift destruction, especially derived from anthropic actions, with a consequent loss and extinction of species and populations, many of them unknown to science (Wilson 1985, 1999, Brooks et al. 2002, Brook et al. 2006, Laurence 2007, Costa et al. 2012). These environmental impacts and habitats loss are not restricting to terrestrial ecosystems, but also occur in freshwater environments, caused by several human activities, such as construction of dams; hydropower expansion; aquaculture, introduction non-native species; agriculture; mining; among others (Agostinho et al. 2008, Azevedo-Santos et al. 2018, Lima Junior et al. 2018). This quick biodiversity loss and natural habitats degeneration create scarcity in data and complete information regarding fauna and flora.

This panorama becomes even more critic due to low investment in projects related to taxonomy, especially non-applied taxonomy (basic) and the training of taxonomists; lack of professionals and capable taxonomists; lack of funding for the maintenance and expansion of the collections of natural history museums and scientific collections; and the insufficient number of taxonomic studies associated to areas of great biodiversity. Such problematic can be translated as "the crisis of biodiversity" (Wheeler 2008). Information about the biological diversity and the identification and description of new species and other taxa is the starting point for all basic or applied studies related to the life sciences. The ability to name and identify them is crucial for any study that uses living organisms, such as ecological, conservation, ethology, evolutionary and other kinds of studies (Savage 1995, Wheeler 2008). The improvement of the knowledge related to systematics, taxonomy, ecology and distribution of our fauna and flora is of fundamental relevance in the current context of Brazilian and world development, mainly for the conservation of species (Wilson 1985, Brooks et al. 2002, Brook et al. 2006, Lewinsohn 2006, Laurence 2007, Wheeler 2008, Costa et al. 2012). Estimates indicate that about 90% of the living species in our planet are still unknown to science. Thus, we know nothing about morphology, ecology, behavior, and geographic distribution of most of our biodiversity (Wheeler 2008). The destruction of habitats at accelerated rates makes identification of new species, the conduction of regional inventories and the taxonomic resolution of species and species groups, before they are extinct, as priority actions. Just this way, appropriate actions and decisions concerning to conservation of species and environments can be made (Wilson 1985, Brooks et al. 2002, Brook et al. 2006, Lewinsohn 2006, Laurence 2007, Wheeler 2008, Nogueira et al. 2010, Costa et al. 2012, 2014, 2018, Thomson et al. 2018).

Most of the protected areas established in Brazil during the past three decades were constituted in order to conserve terrestrial fauna and flora, and many of these areas protect important water bodies (Agostinho et al. 2005). However, there is a huge possibility that the design and the coverage area of these protection units, because they are based on terrestrial biodiversity, are mismatched in the protection and conservation of aquatic ecosystems (Barletta et al. 2010, Herbert et al. 2010, Azevedo-Santos et al. 2018). This mismatch is probably related mainly to the fact that these areas only include stretches of the rivers, streams and hydrographic basins, thus, not including the essential regions that would guarantee a functional and protected freshwater biodiversity and fragmenting the conservation of the water bodies (Rodríguez-Olarte et al. 2011, Azevedo-Santos et al. 2018). Despite this gap, the inclusion of data on freshwater fish fauna, or even aquatic biota in the definition of protected areas has gathered greater attention (Rodríguez-Olarte et al. 2011); however, there still is the need for conducting inventories on ichthyofauna, since these aquatic environments present a significant risk of degradation (Barletta 2010, Azevedo-Santos et al. 2018).

Thus, the objective of our study is to present the list of freshwater fish of the Parque Nacional dos Lençóis Maranhenses (PNLM), an area of environmental protection managed by the federal government, characterized by the presence of dunes, lagoons and small watercourses. Although it is an area of integral protection, the environments contained in the PNLM have been under intense pressure, especially those related to tourism, which is increasing in the region. Most of the areas targeted by tourism are freshwater environments, making them the main attraction (Miranda et al. 2012). In the past two decades, efforts have been made to inventory the freshwater fish fauna and to solve taxonomically some groups occurring on the Maranhão State. However, the knowledge regarding the composition of the Maranhão freshwater fishes is still insufficient and underestimated, with several groups still lacking adequate taxonomic and systematic resolution, and with many gaps of knowledge (Piorski 2010, Guimarães et al. 2018a). In a context of "freshwater biodiversity crisis" (sensu Harrison et al. 2018), this is not appropriate.

Material and Methods

1. *Study area*

The PNLM is a protected area located at the eastern coastal region of Maranhão, within the territorial limits of Primeira Cruz, Santo Amaro do Maranhão and Barreirinhas municipalities, with a coastline extending for 270 km and a total area of 155,000 hectares. This area is constituted by dunes interspersed by perennial and temporary lagoons, rivers, streams and lakes. It includes two main coastal river basins: Preguiças and Periá. The dunes present in the park, which are the reason for the denomination of Lençóis Maranhenses, are constituted of eolic and marine deposits of the Quaternary period, configuring an extensive area of free and fixed dunes (ICMBio 2003). Besides the dunes, the park also comprises a mosaic of ecosystems such as mangroves, riparian forest and restinga, the latter being predominant in the region (ICMBio 2003).

2. *Sampling design*

Collection of samples was conducted at 21 collecting sites distributed within and outside the boundaries of PNLM, comprising rivers, streams, lagoons and lakes (Table 1, Figures 1, 2), along the basins of rivers Preguiças and Periá. Sampling was conducted in three expeditions: the first ones taking place in 2000 in the mouths of July and December, and in 2017 in the month of July.

3. *Collection and identification of specimens*

Fishes were collected with two seines (20 m long, 2.5 m high, mesh size 10 mm; and 4 m long, 2 m height, mesh size 5 mm), cast nets (2 m height, mesh size 15 mm), gillnets of various mesh sizes (15, 25, 35, 45 and 55 mm), and dip nets (mesh size 5 and 10 mm). The ichthyological material obtained in the samples was fixed in the field using 10% formalin solution neutralized with sodium tetraborate. Some specimens were photographed alive in order to obtain records of their natural coloration. Sorting and identification of specimens were carried out at the Laboratório de Sistemática e Ecologia de Organismos Aquáticos of the Universidade Federal do Maranhão and at the Laboratório de Ecologia e Sistemática de Peixes, from the same institution, using specialized bibliography for each taxonomic group and consulting experts. The ichthyological material was deposited in the Coleção de Peixes da Universidade Federal do Maranhão (CPUFMA) and Coleção Ictiológica do Centro de Ciências Agrárias e Ambientais of the Universidade Federal do Maranhão (CICCAA). The taxonomic classification follows Nelson et al. (2016); and the name, authors, year of publication, validity, distribution and updated data of each species were checked in Fricke et al. (2019).

Table 1. Collecting sites within the Parque Nacional dos Lençóis Maranhenses and adjacent areas.

Site	Locality	River basin	Municipality	Coordinates
1	Baixa Grande	Rio Preguiças	Barreirinhas	2° 32.3'S 42° 59.10'W
2	Lago de Santo Amaro	Rio Periá	Santo Amaro	2° 28.20'S 43° 13.98'W
3	Lago da Betânia	Rio Periá	Santo Amaro	2° 33.05'S 43° 11.02'W
4	Lagoa da Esperança	Rio Preguiças	Barreirinhas	2° 41.58'S 43° 2.35'W
5	Ponta do Mangue	Rio Preguiças	Barreirinhas	2° 34.53'S 42° 47.51'W
6	Queimada dos Britos	Rio Preguiças	Barreirinhas	2° 30.51'S 43° 1.87'W
7	Riacho Mata-Fome, Tucunzal	Rio Preguiças	Barreirinhas	2° 39.68'S 42° 48.83'W
8	Rio Alegre em Boa Vista	Rio Periá	Primeira Cruz	2° 28.60'S 43° 18.98'W
9	Rio Grande, na Ponta do Espigão	Rio Periá	Santo Amaro	2° 32.36'S 43° 11.79'W
10	Rio Santo Inácio, em Atins	Rio Preguiças	Barreirinhas	2° 34.44'S 42° 44.84'W
11	Rio Sucuriju	Rio Preguiças	Barreirinhas	2° 39.21'S 42° 46.92'W
12	Lago de Travosa	Rio Periá	Santo Amaro	2° 23.42'S 43° 15.76'W
13	Lagoa no Riacho Tucuns	Rio Preguiças	Barreirinhas	2° 43.2'S 42° 51.19'W
14	Riacho Achuí - Tucuns	Rio Preguiças	Barreirinhas	2° 43.24'S 42° 51.83'W
15	Riacho Sucuriju, Povoado Cedro	Rio Preguiças	Barreirinhas	2° 42.07'S 42° 49.23'W
16	Rio Sucuriju, em Tucunzal	Rio Preguiças	Barreirinhas	2° 39.91'S 42° 49.74'W
17	Riacho em Tucunzal	Rio Preguiças	Barreirinhas	2° 39.79'S 42° 49.87'W
18	Rio das Pedras	Rio Periá	Santo Amaro	2° 47.89'S 43° 15.37'W
19	Rio Juçaral	Rio Preguiças	Barreirinhas	2° 49.42'S 43° 07.34'W
20	Riacho Passagem do canto	Rio Preguiças	Barreirinhas	2° 50.77'S 42° 51.82'W
21	Morro do Boi	Rio Preguiças	Barreirinhas	2° 37.19'S 42° 41.02'W

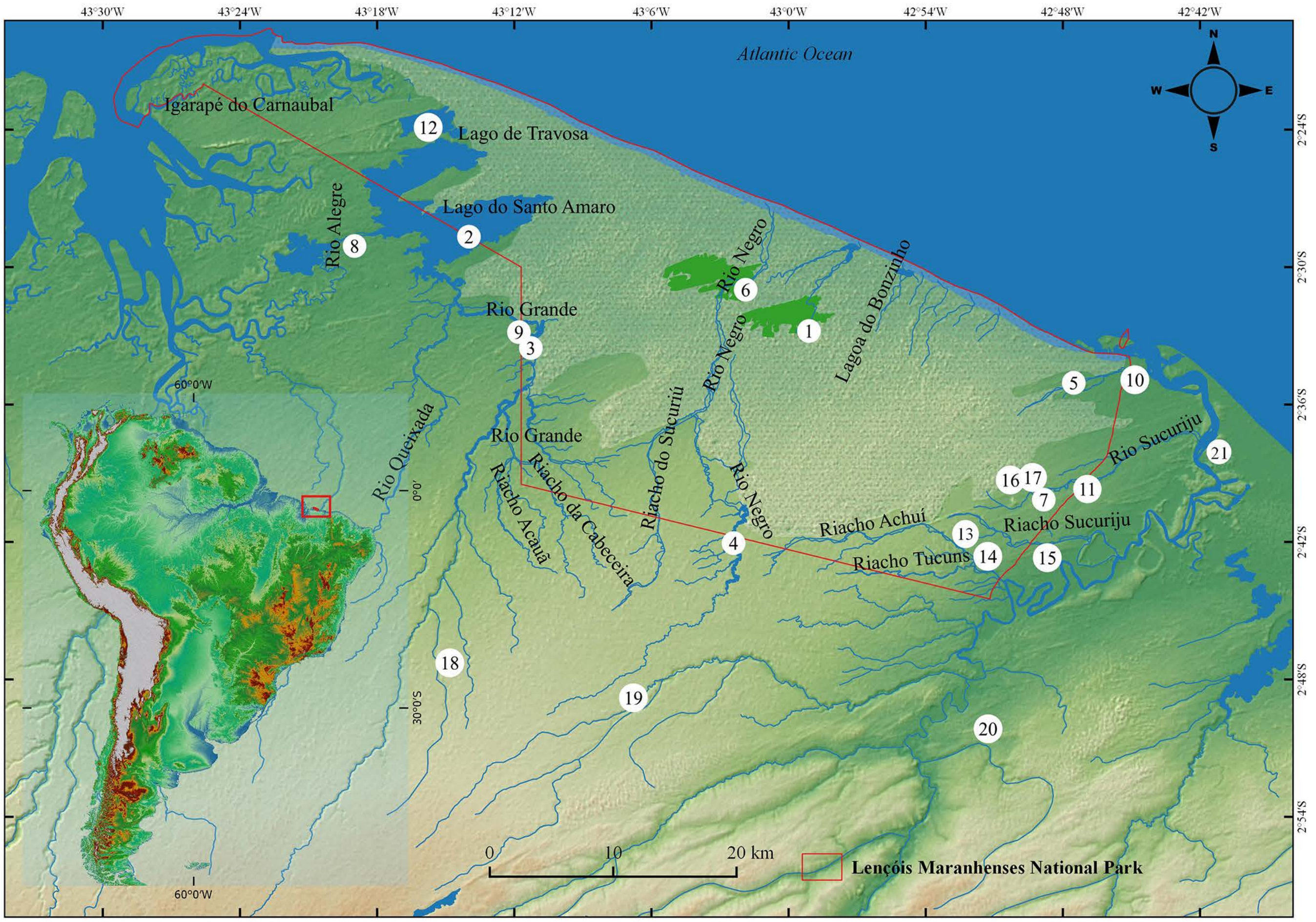

Figure 1. Collecting sites in the Parque Nacional Lençóis Maranhenses, northeastern Brazil, and adjacent areas.

Figure 2. Some collecting sites at PNLM.

Results

The fish survey of the freshwater rivers (including some river estuaries) of Parque Nacional dos Lençóis Maranhenses reported 49 species, representing 10 orders and 25 fish families that range from obligate freshwater to estuarine organisms. Thirty-three of these species were identified accurately at the species level (Table 2). The Orders comprising the highest percentage of species richness, excluding non-native species, were: Characiformes (46%), Siluriformes (11%), Cichliformes (11%), and Gymnotiformes (10%) (Figure 3), representing 78% of the total species richness. Cyprinodontiformes (*Anablepsoides* Huber, 1992*, Melanorivulus* Costa 2006 and *Poecilia* Bloch & Schneider 1801)*,* Perciformes (*Eucinostomus* Baird & Girard 1855 and *Polydactylus* Lacepède 1803), Clupeiformes (*Lycengraulis* Günther 1868), Gobiiformes (*Awaous* Steindachner 1861), Mugiliformes (*Mugil* Linnaeus 1758), Synbranchiformes (*Synbranchus* Bloch 1795), Pleuronectiformes (*Achirus* Lacepède 1802) complete the list with four, two, one species each respectively (Table 2, Figure 3). The families with the highest number of species, excluding non-native species, were: Characidae, with 11 species, representing 22% of the species, followed by Cichlidae, with five species (10%), and Loricariidae with three (6%) (Figure 4).

Table 2. List of species collected at the PNLM. New records marked with*.

Classe ACTINOPETRYGII	
Ordem CLUPEIFORMES	
Família Engraulidae	
Lycengraulis batesii (Günther, 1868)	CPUFMA001178
Ordem CHARACIFORMES	
Família Acestrorhynchidae	
Acestrorhynchus falcatus (Bloch, 1794)	CPUFMA172189
Família Anostomidae	
Leporinus aff. *friderici*	CPUFMA001137
Família Characidae	
Astyanax cf. *lacustris*	CPUFMA172807
Brachychalcinus parnaibae Reis, 1989*	CPUFMA001268
Hyphessobrycon piorskii Guimarães, Brito, Feitosa, Carvalho-Costa & Ottoni 2018	CICCAA02051
Hemigrammus sp1. *	CICCAA02140
Hemigrammus sp.2*	CICCAA02158
Hemigrammus sp.3*	CICCAA02119
Moenkhausia cotinho Eigenmann, 1908	CICCAA02085
Moenkhausia oligolepis (Günter, 1864) *	CICCAA02102
Moenkhausia sp.	CPUFMA172770
Poptella compressa (Günther 1864) *	CPUFMA001194
Serrapinus sp. *	CPUFMA001293
Família Curimatidae	
Steindachnerina notonota (Miranda Ribeiro, 1937)	CPUFMA001180
Curimatopsis aff. *cryptica*	CPUFMA172802
Família Erythrinidae	
Hoplias malabaricus (Bloch, 1794)	CPUFMA172190
Hoplerythrinus unitaeniatus (Agassiz, 1829)	CPUFMA172196
Família Iguanodectidae	
Bryconops cf. *affinis* *	CPUFMA172773
Bryconops cf. *melanurus**	CPUFMA172806
Família Lebiasinidae	
Nannostomus beckfordi Günther, 1872	CPUFMA172204
Família Serrasalmidae	
Serrasalmus rhombeus (Linnaeus, 1766)	CPUFMA001158
Metynnis lippincottianus (Cope, 1870)	CPUFMA001176

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Ordem CICHILIFORMES	
Família Cichlidae	
Apistogramma piauiensis Kullander, 1980	CPUFMA172193
Aequidens tetramerus (Heckel, 1840)	CPUFMA001230
Cichlasoma cf. *zarskei*	CPUFMA172191
Crenicichla brasiliensis (Bloch 1792)	CPUFMA001288
Oreochromis sp.	CPUFMA001191
Satanoperca jurupari (Heckel, 1840)	CPUFMA001251
Ordem CYPRINODONTIFORMES	
Família Poeciliidae	
Poecilia vivipara Bloch & Schneider, 1801	CPUFMA001214
Poecilia sarrafae Bragança & Costa, 2011*	CPUFMA001216
Família Rivulidae	
Melanorivulus cf. *parnaibensis* *	CPUFMA172782
Anablepsoides vieirai Nielsen 2016*	CPUFMA172801
Ordem GYMNOTIFORMES	
Família Apteronotidae	
Apteronotus albifrons (Linnaeus, 1766)	CPUFMA001173
Família Gymnotidae	
Gymnotus carapo Linnaeus, 1758	CPUFMA001174
Família Hypopomidae	
Brachyhypopomus sp.*	CPUFMA172800
Família Sternopygidae	
Eigenmannia virescens (Valenciennes, 1836)	CPUFMA001165
Sternopygus macrurus (Bloch & Schneider, 1801)	CPUFMA001166
Ordem MUGILIFORMES	
Família Mugilidae	
Mugil curema Valenciennes, 1836	CPUFMA001181
Ordem PERCIFORMES	
Família Gerreidae	
Eucinostomus cf. *argenteus*	CPUFMA001218
Família Polynemidae	
Polydactylus virginicus (Linnaeus, 1758)	CPUFMA001195
Família GOBIIFORMES	
Ordem GOBIIDAE	
Awaous tajasica (Lichteinstein, 1822)	CPUFMA001183
Ordem PLEURONECTIFORMES	
Família Achiridae	
Achirus achirus (Linnaeus, 1758)	CPUFMA001186
Ordem SILURIFORMES	
Família Auchenipteridae	
Trachelyopterus galeatus (Linnaeus, 1766)	CPUFMA001131
Família Callichthyidae	
Megalechis thoracata (Valenciennes,1840) *	CPUFMA172194
Família Heptapteridae	
Pimelodella parnahybae Fowler, 1941	CPUFMA00242
Família Loricariidae	
Loricaria cf. *parnahybae*	CPUFMA001160
Hypostomus johnii (Steindachner, 1877)	CPUFMA002174
Ordem SYNBRANCHIFORMES	
Família Synbranchidae	
Synbranchus marmoratus Bloch, 1795	CPUFMA001192

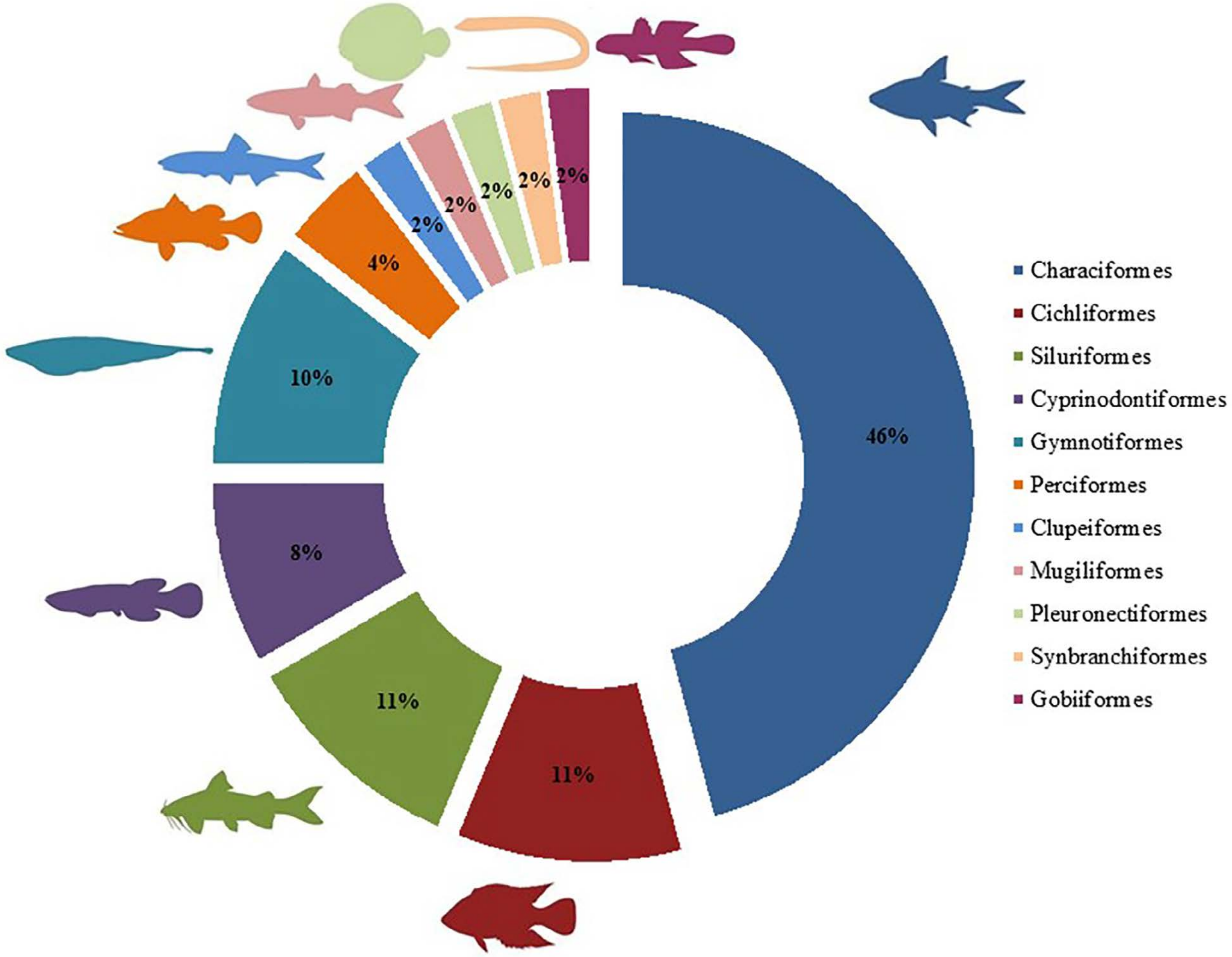

Figure 3. Ranking of richness by Orders observed in the PNLM, excluding non-native species.

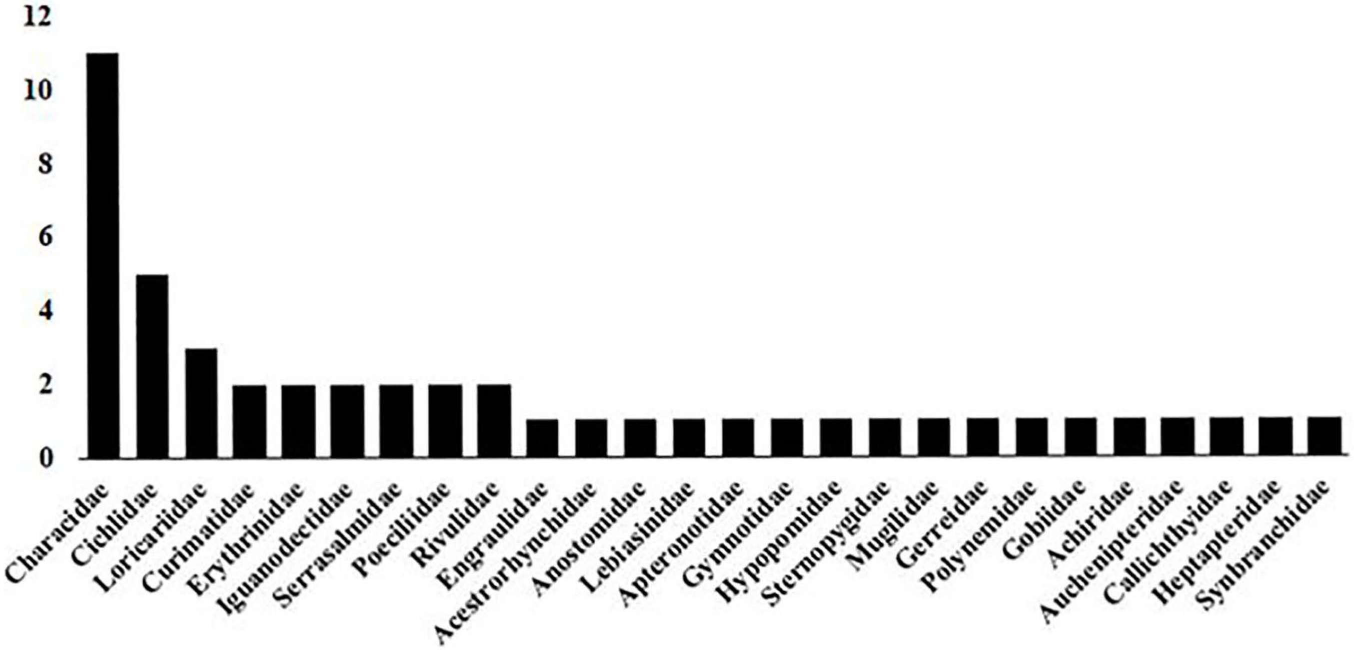

Figure 4. Ranking of richness by families observed in the PNLM, excluding non-native species.

Discussion

One of the few ichthyofauna studies conducted at the PNLM was the paper published by Garavello et al. (1998) which provided a preliminary list of fishes occurring on the sand dune lagoons of the park. They listed 13 species, one of them possessing a marine habit [*Arius spixii* (Agassiz, 1829)], and 12 freshwater species. In this preliminary list of fishes, Characiformes was the most diverse order; and despite the small number of species recorded by Garavello et al. (1998), the pattern of species richness did not differ from other freshwater fish inventories [e.g. Barros et al. 2011 (Itapecuru river basin), Claro-Garcia & Shibatta 2013 (upper Tocantins river basin), Ramos et al. 2014 (Parnaíba river basin), Melo et al. 2016 (Parnaíba river basin)]. The fish survey provided by our work reported 49 species occurring on freshwater habitats at the PNLM (including some river estuaries), representing ten orders and 25 fish families, that range from obligate freshwater to estuarine organisms (Table 2, Figure 1). This is more than three times the number of freshwater species (12) reported by Garavello et al. (1998) and furthermore added 16 species to the list provided by Piorski et al. (2017), including 14 new records for PNLM (Table 2). From the 12 freshwater species listed by Garavello et al. (1998), all the species, four of them except, were reported by our survey: *Curimata* sp., *Colossoma* sp., *Crenicichla* aff. *lugubris*, and *Aequidens pallidus* (Heckel 1840). Therefore, we opted to not consider them in our survey, since we collected other congeners or close related genera to these four species registered by Garavello et al. (1998), and a hypothesis of misidentification of these species by them is not rejected. In addition, neither *A. pallidus* nor *C. lugubris* have official distribution records for the studied area, nor for nearby regions, and their type localities are very far from PNLM (see Kullander 2003, Fricke et al. 2019), what makes the records of these two species for this protected area unlikely.

Among the 49 freshwater species recorded in this study, 14 are new records for the PNLM. From these 49 species, just one corresponds to an introduced one (*Oreochromis* sp.). The occurrence of this non-native species highlights the importance of long-term monitoring the populations of this species, attempting to control the populations, reducing the possible impacts over the natural freshwater community. Protected areas with non-native species are more challenge. Among the 14 new records in the PNLM, cited above, as well as some of the 16 species which we were unable to identify accurately at the species level, could include undescribed species, but more study is necessary before sorting out which species are truly undescribed and which are already described ones. The orders reported by this survey comprising the highest percentage of species richness were Characiformes (46%), Siluriformes (11%), Cichliformes (11%), and Gymnotiformes (10%), excluding non-native species (Figure 2), as expected for Neotropical freshwater surveys (e.g. Langeani et al. 2007, Lucinda et al. 2007, Sarmento-Soares et al. 2007, Vari et al. 2009, Casatti et al. 2013, Ramos et al. 2014, Polaz et al. 2014, Fagundes et al. 2015, Melo et al. 2016, Cetra et al. 2016).

When comparing the present survey with inventories from other river drainages from the Maranhão State, we can conclude that the freshwater fish fauna of the state is probably still underestimated, as argued by Piorski (2010) and Guimarães et al. (2018a). In hydrographic terms, the PNLM boundaries include the Preguiças and Periá river basins. These two coastal river basins are very small when compared to the major coastal river basins of the Maranhão-Piauí ecoregion, such as Parnaíba, Mearim, Turiaçu, Itapecuru and Gurupi river basins. However, in terms of recorded biodiversity, we have a substantial number of species from these two basins. The 49 species herein recorded represent three times the number of freshwater species (13) reported by Matavelli et al. (2015) for the Munim, Parnaíba and other smaller coastal river basins, as well as more than twice the number of species (20) reported by Ribeiro et al. (2014) for the Munim river basin. It has just 11 species less than the number of species (60) reported by Soares (2013) for the Mearim river basin; just 20 species less than the number of species (69) reported by Barros et al. (2011), and 15 species less than the survey (64) performed by Nascimento et al. (2016), respectively, for the Itapecuru river basin, one of the major coastal river basins of this ecoregion; and just 16 species less than the inventory (65) published by Melo et al. (2016) for the Parnaíba river basin, the major coastal river basin of the Maranhão-Piauí ecoregion and one of the main river basins of Brazil. The two surveys including more species recorded from coastal river basins of the Maranhão state were the works published by Ramos et al. (2014) for the Parnaíba river basin, and the survey provided by Castro & Dourado (2011) for the Mearim, Pindaré, Pericumã and upper Turiaçu river drainages, including 146 and 109 species, respectively. The first one was an exhaustive inventory of one of the main and largest river basin of Brazil (Parnaíba), and the second one included three distinguished river drainages: Mearim and Pindaré from the Mearim river system, the second major river system of the Maranhão-Piauí ecoregion, and Turiaçu, one of the main river basins of this ecoregion. Even so, our survey recorded about a half to one third of the number of species than these two surveys cited above, what demonstrates the effort put in the inventory here presented.

From the 33 species herein identified accurately at the species level, five of them, *Achirus achirus* (Linnaeus 1758), *Awaous tajasica* (Lichtenstein 1822), *Mugil curema* Valenciennes 1836, *Poecilia vivipara* Bloch & Schneider 1801 and *Polydactylus virginicus* (Linnaeus 1758), are species typically found in brackish water environments, and when occurring on freshwater environments, are restricted mainly to estuaries, or, occasionally, the lower portions of the rivers. Thus, we will not address them in our biogeographical comments. From the remaining 28 species, eight did not occur in the Amazon River basin (*Anablepsoides vieirai* Nielsen 2016, *Apistogramma piauiensis* Kullander 1980, *Crenicichla brasiliensis* (Bloch 1792), *Hyphessobrycon piorskii* Guimarães, Brito, Feitosa, Carvalho-Costa & Ottoni 2018, *Hypostomus johnii* (Steindachner 1877), *Poecilia sarrafae* Bragança & Costa 2011, *Pimelodella parnahybae* Fowler 1941 and *Steindachnerina notonota* (Miranda Ribeiro 1937); six of them (*A. vieirai, A. piauiensis, H. piorskii, H. johnii, P. sarrafae* and *P. parnahybae*) being endemic to the Maranhão-Piauí ecoregion (see Fricke et al. 2019). All the remaining species herein reported have their distribution recorded for the Amazon River basin (see Fricke et al. 2019), which shows the great influence of the Amazon basin.

According to Rosa et al. (2003), the fish fauna on Maranhão-Piauí ecoregion was historically pointed out as poorly endemic. Otherwise, the low level of endemism recorded during the past decades would be related to less sampling effort on the whole region (Piorski 2010, Ramos et al. 2014, Guimarães et al. 2018a). Several species in the Maranhão-Piauí rivers are known to occur along the Amazon basin (including coastal rivers in Suriname and the Guianas), a distribution pattern suggested by Barros et al. (2011), who observed a predominance of Amazonian species in the Itapecuru basin, as well as corroborated for some putative species by Guimarães et al. (2016, 2017a, b). In addition, this influence of the Amazon River basin in the ecoregion was advocated by Hubert & Renno (2006) and Dagosta & de Pinna (2017), in their biogeographic analyses. However, these same authors also advocated the possibility of the coastal river basin of the Maranhão state constituting one or more areas of endemism. However, both papers suggest that data related to the freshwater ichthyofauna from this region are too scarce to have a more conclusive hypothesis. Guimarães et al. (2018a) provided a list of several species that are endemic to the river drainages of the Maranhão state or occur just on neighboring areas. This fortifies the hypothesis that the coastal river basins of the Maranhão state could constitute one or more areas of endemism. In addition, a new species (*H. piorskii*) was recently described by Guimarães et al. (2018b) with its distribution known to be restricted to the Munim and Preguiças River basins (including the freshwater bodies of the PNLM). As pointed out above, some of the species which we were not able to identify accurately at the species level could be undescribed ones, and more studies and research need to be done, preferably including molecular data, since many of them are member of species complexes (some of them including cryptic species) or groups still poorly resolved taxonomically. In terms of conservation, the PNLM has a key role in the conservation of the six species, cited above, endemic to the Maranhão-Piauí ecoregion, since it is the most internationally appreciated and subsidized protected area of the ecoregion, which contributes to the preservation of these species, especially the endemic species of the region.

The PNLM presents a unique scenic beauty, appreciated internationally. However, knowledge about existing biodiversity does not follow the same standards. Information on the biota diversity in the limits of its area dates back to the beginning of the 2000s when studies were carried out to prepare the management plan of the protected area (ICMBio 2003). According to these studies, the fauna diversity is relatively low compared to other regions. In general, the fauna consists of 17 groups of mammals, 112 bird species, including migratory species (ICMBio 2003) and 42 species of reptiles (Miranda et al. 2012). As well as the other Brazilian protected areas, the PNLM fails to preserve its freshwater environment properly, since it includes only fragments of the major river systems of the area, not including and conserving the hole river drainages, mainly excluding their headwaters (see Figure 2). Thus, its water bodies are exposed to typical human impacts, as discussed by Azevedo-Santos et al. (2018).

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Beldo Rywllon Abreu Ferreira: Contribution for data collection, to taxonomic identification of fishes and contributed to manuscript preparation

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Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Bombacoideae, Byttnerioideae, Grewioideae and Helicterioideae (Malvaceae *s.l.*) in the Raso da Catarina Ecoregion, Bahia, Brazil

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Abstract: This work presents a floristic survey of the subfamilies Bombacoideae, Byttnerioideae, Grewioideae and Helicterioideae (Malvaceae *s.l.*) in the Raso da Catarina Ecoregion (RCE), Bahia, Brazil. The samples analyzed were collected from September 2013 to May 2015. The analyses were supplemented with dried collections kept in the herbaria: ALCB, HRB, HUEFS, HUNEB, HST, IPA, PEUFR, R and RB. The identifications were based mainly on specialized bibliographies, protologues, types and herbaria collections. Ten genera and 22 species of the subfamilies were recorded, nine endemic to Brazil. *Waltheria* L. was the most representative genus with five species, followed by *Ceiba* Mill. and *Melochia* L. with three species each, *Helicteres* L., *Luehea* Willd., *Pachira* Aubl. and *Pseudobombax* Dugand presented two species each and other genera were represented by one species each. Among the species recorded, *Luehea candicans* Mart. represents a new record for the Caatinga biome. The species most commonly found in the study area were *Helicteres velutina* K.Schum., *Melochia tomentosa* L., *Waltheria brachypetala* Turcz., *W. indica* L. and *W. rotundifolia* Schrank. The taxonomic treatment includes identification key, descriptions, illustrations, photos, geographical distribution, reproductive phenology and comments about all studied species.

Keywords: *biodiversity, Caatinga, morphology, semiarid, taxonomy.*

Bombacoideae, Byttnerioideae, Grewioideae e Helicterioideae (Malvaceae *s.l.*) na Ecorregião Raso da Catarina, Bahia, Brasil

Resumo: Este trabalho apresenta o levantamento florístico das subfamílias Bombacoideae, Byttnerioideae, Grewioideae e Helicterioideae (Malvaceae *s.l.*) na Ecorregião Raso da Catarina, Bahia, Brasil. Os espécimes analisados foram coletados no período de setembro/2013 a maio/2015. As análises foram complementadas com coleções herborizadas depositadas nos herbários: ALCB, HRB, HUEFS, HUNEB, HST, IPA, PEUFR, R e RB. As identificações foram realizadas com base, principalmente, em bibliografias especializadas, protólogos, imagens de coleções-tipo e consultas às coleções dos herbários visitados. Foram registrados 10 gêneros e 22 espécies para as subfamílias, sendo nove endêmicas do Brasil. *Waltheria* L. foi o gênero mais representativo com cinco espécies, seguido por *Ceiba* Mill. e *Melochia* L. com três espécies cada, *Helicteres* L., *Luehea* Willd., *Pachira* Aubl. e *Pseudobombax* Dugand apresentaram duas espécies cada e os demais gêneros foram representados cada um por uma única espécie. Entre as espécies catalogadas, *Luehea candicans* Mart. é um novo registro para o bioma Caatinga As espécies mais frequentes na área de estudo foram *Helicteres velutina* K.Schum., *Melochia tomentosa* L., *Waltheria brachypetala* Turcz., *W. indica* L. e *W. rotundifolia* Schrank. O tratamento taxonômico inclui uma chave para a identificação, descrições, ilustrações, fotografias, dados de distribuição geográfica, fenologia reprodutiva e comentários sobre todas as espécies estudadas.

Palavras-chave: *biodiversidade, Caatinga, morfologia, semiárido, taxonomia.*

Introduction

The family Malvaceae, as currently circumscribed, has a Cosmopolitan distribution, but is predominantly Pantropical, comprising about 250 genera and 4,200 species (Bayer & Kubitzki 2003). There are about 73 genera and 783 species in Brazil, of which approximately 290 are distributed in the Northeast Region and 161 in the Caatinga, with more than 50% of the species that occur in the country being endemic (Bovini et al. 2015, BFG 2015).

In traditional classification systems, Malvaceae*,* Bombacaceae, Sterculiaceae and Tiliaceae were included in the order Malvales as distinct families (Dahlgren 1980, Takhtajan 1980, Cronquist 1988). However, in recent decades, morphological, anatomical, palynological and chemical studies (Judd & Manchester 1997), associated with phylogenetic analyses based on molecular data (Alverson et al. 1999, Bayer et al. 1999, Nyffeler et al. 2005), have shown that the separation of these four families is inconsistent. For this reason, Bombacaceae, Sterculiaceae and Tiliaceae were circumscribed within Malvaceae *s.l.,* a monophyletic group characterized by the presence of nectaries consisting of glandular trichomes located internally at the base of the calyx or, less commonly, on the petals or androgynophore (Judd & Manchester 1997, Bayer et al*.* 1999, Vogel 2000, Judd et al*.* 2009).

Phylogenetic studies based on molecular data of Malvaceae *s.l.* recognized nine subfamilies. Of these, Bombacoideae includes the remnants of Bombacaceae, after the removal of two tribes, and along with Malvoideae form a well-sustained clade called Malvatheca. Byttnerioideae contains the tribes Byttnereae, Hermannieae, Lasiopetaleae and Theobromeae (cacau and allies of the family Sterculiaceae), and Grewioideae consists of the tribes Grewieae and Sparrmannie, previously treated in Tiliaceae. Together Byttnerioideae and Grewioideae form the Byttneriina clade. The subfamily Helicteroideae consists of the tribe Helictereae (formerly classified in Sterculiaceae) and Durioneae (formerly classified in Bombacaceae) (Alverson et al. 1999, Bayer et al. 1999, Bayer & Kubitzki 2003, Baum et al. 2004).

The subfamilies of Malvaceae are distributed in tropical regions of the New and Old World, except for Tilioideae, which occurs in the Northern Hemisphere; Bombacoideae, which is mainly Neotropical but with some representatives in the tropics of the Old World; and Malvoideae, which occurs in temperate regions of all continents, but predominantly in tropical regions of the New World (Bayer & Kubitzki 2003). In Brazil, the subfamilies are represented throughout the country and among all phytogeographic domains (Bovini et al. 2015). Many of these species are of great economic importance, such as cacau (*Theobroma cacao* L.) and cupuaçu (*Theobroma grandiflorum* (Willd. ex Spreng.) K.Schum.), which are used for food and medicine; and the paineiras [*Ceiba speciosa* (A.St.-Hil., A.Juss. & Cambess.) Ravenna and *C. pubiflora* (A.St.-Hil.) K.Schum.] and carolina [*Pachira aquatica* Aubl.], which stand out as ornamentals. The African species Baobá (*Adansonia digitata* L.) is considered one of the most robust on the planet. Notable in natural ecosystems are the genera *Luehea* Willd., common in seasonal forests; *Helicteres* L. in the Cerrado and flooded areas; *Triumfetta* L. and *Waltheria* L., which have species considered invasive of crops; the barrigudas (*Cavanillesia* Ruiz & Pav. e *Ceiba* Mill.) and embiruçus (*Pseudobombax* Dugand) in the Caatinga, which are important producers of fiber (Sampaio et al. 2005, Lorenzi & Matos 2008, Souza & Lorenzi 2012, Kinupp & Lorenzi 2014).

Some taxonomic studies of the genera subordinate to these subfamilies include the reviews like *Triumfetta* L. (Lay 1950), *Bombax* L. (Robyns 1963), *Ceiba* Mill (Gibbs & Semir 2003), *Ayenia* L., *Byttneria* Loefl., *Rayleya* Cristóbal and *Helicteres* L. (Cristóbal 1960, 1976, 1981, 2001), *Melochia* L. (Goldberg 1967, Rondón 2007) and *Waltheria* L. (Saunders 1995). Among floristic inventories are those for Argentina (Cristóbal 1998), Panama (Robyns 1964a,b, Robyns & Cuatrecasas 1964) and Paraguay (Cristóbal 2007).

For Brazil, important taxonomic treatments of the families Bombaceae, Tiliaceae, Sterculiaceae and Malvaceae were performed by Saint-Hilaire (1825-1827) in *Flora brasiliæ meridionalis* and Schumann (1886) in *Flora Brasiliensis.* Other relevant studies treated these groups in lists or monographic studies of state flora, such as the Flora da Serra do Cipó (Esteves 1986); Flora de Mucugê (Cristóbal & Tressens 1986); Flora do Pico das Almas (Cristóbal et al. 1995); Flora de Mirandiba (Amorim et al. 2009), Flora da Reserva Ducke (Vicentini & Silva 1999, Esteves 2005); Flora de Grão-Mogol (Cristóbal 2006); Flora de São Paulo (Souza & Esteves 2002, Duarte et al. 2007, Cruz & Esteves 2009) and Flora de Sergipe (Amorim 2013). Also noteworthy are revisions of the genera *Pseudobombax* Dugand for Bahia (Carvalho-Sobrinho 2006), *Eriotheca* Schott & Endl. in Brazil (Duarte 2010), *Melochia* L. in the Southeast Region (Gonçalez & Esteves 2017), Malvaceae of Parque Estadual do Ibitipoca (Fernandes-Júnior & Konno 2017) and Flora of the canga of the Serra dos Carajás, Pará (Fernandes-Júnior & Cruz 2018). Nonetheless, there remains a great shortage of studies of these subfamilies in the Caatinga.

Despite the existence of studies about subfamilies from the Brazilian semiarid, regional studies on this family within the state of Bahia are scarce, especially those that include identification keys and morphological descriptions for the family. Considering the importance of the subfamilies in the Brazilian flora, and the gap of information regarding these groups in the Caatinga biome, this study aimed to elaborate a taxonomic study of subfamilies within the Raso da Catarina Ecoregion (RCE) in the state of Bahia and to provide information in support of the development of management plans for the conservation units of the Ecoregion.

Material and Methods

The Raso da Catarina Ecoregion (RCE) comprises an area of 30.800 km^2, being one of the eight Ecoregions recognized for the Caatinga biome in Brazil. In the North-South direction it is narrow and elongated. In the North, West and East it is limited to the southern hinterland depression. The northeastern portion borders with the Borborema Plateau in the state of Pernambuco, and the southern part borders with hinterlands in the state of the Bahia. The Ecoregion is a sedimentary basin with a very flat relief, showing canyons formed by sandstone outcrops only in the western part. Altitudes above sea level vary from 400 to 600 m in the southern part (state of Bahia) and from 350 to 700 m in the northern part (Jatobá basin, state of Pernambuco). In the southern part (state of Bahia) most of the soils are composed of sand (deep, excessively drained, acid and very low fertility) and oxisol (deep, well drained, acid and low fertility) whereas in the northern part (Pernambuco) sandy soils prevail. Water availability is scarcein the region, except in the areas of the canyons. The predominant vegetation is woodland Caatinga in sandy soils, and thorny over crystalline soils (Velloso et al. 2002).

The climate of the Ecoregion is characterized as semiarid with average rainfalls of 650 mm/year in the southern part (state of Bahia), with rainy season from December to July. In the northern part (state of Pernambuco) the climate is drier with average rainfalls of 450 mm/year, with rainy season from January to April. Temperatures are very high, ranging from 24 °C to 30 °C (Velloso et al. 2002, Paes & Dias 2008). The municipalities in this Ecoregion in the state of Bahia are: Canudos, Chorrochó, Cícero Dantas, Euclides da Cunha, Glória, Jeremoabo, Macururé, Paulo Afonso, Rodelas, Santa Brígida and Uauá. The Ecoregion includes six conservation units, five located in its southern part in the state of Bahia: Ecological Station Raso da Catarina, Environmental Preservation Area Serra Branca (EPASB), State Park of Canudos, Biological Station of Canudos, Private Reserve of Natural Heritage (PRNH) Farm Flor de Lis and Biological Reserve of Serra Negra, located in the northern part, in the state of Pernambuco (Velloso et al. 2002, Szabo et al. 2007).

This study was based on fieldwork carried out from September 2013 to May 2015 during random walks exploring most of the study area. Fieldwork expeditions focused mainly conservation units (Figures 1, 2) within the southern part of the Ecoregion, in the state of Bahia: Environmental Protection Area Serra Branca- EPASB (09°53’15.5” to 09°44’34.6” S and 38°49’36.1” to 38°52’20.4” W), Biological Station of Canudos- BSC (09°55’58.6” to 09°58’25.2” S and 38°57’32.2” to 39°01’38.5” W), Ecological Station of Raso da Catarina – ESRC (09°33’13” to 09°54’30” S and 38°29’20” to 38°44’00” W), State Park of Canudos – SPC (09°56’19.7” to 09°54’32.4” S and 39°06’13.3” to 39° 04’20.5” W), and PRNH Farm Flor de Lis (10°50’14.1” to 10°50’26.4” S and 38°31’46.4” to 38°31’34.7” W) (Vieira et al. 2015).

Herborization of specimens followed Fosberg & Sachet (1965), and Mori et al. (1989), and observations on soil types followed Tricart (1972), and Sampaio (1995). All collected specimens were deposited at HUNEB herbarium (Paulo Afonso Collection), and duplicates were sent to herbaria in the state of Bahia. Additional herbarium specimens from Brazilian herbaria were analyzed (ALCB, HRB, HUEFS, HUNEB, IPA, PEUFR, R and RB, acronyms according to Thiers 2018 (continuously updated, Appendix 1), and in the herbaria HST, acronyms according to the Brazilian network of herbaria (SBB 2018). Identifications were made based on specialized literature (e.g., Robyns 1963, Robyns & Cuatrecasas 1964, Cristóbal 2001, Du Bocage & Sales 2002, Tschá

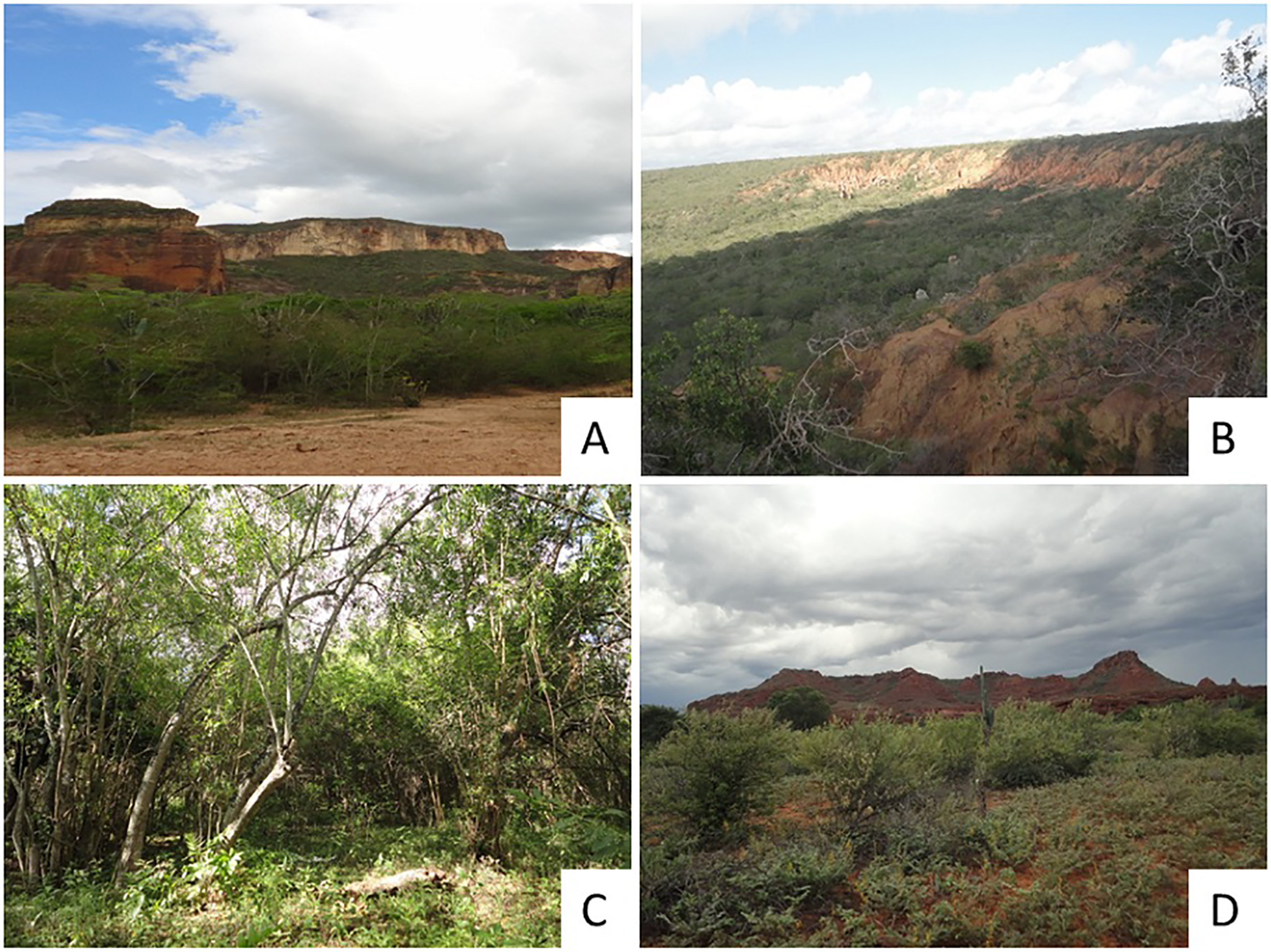

Figure 1. Units of Conservation of the Raso da Catarina Ecoregion, part Bahia, Brazil. A. Environmental Protection Area Serra Branca; B. Ecological Station Raso da Catarina; C. PRNH Farm Flor de Lis; D. Biological Station of Canudos. Photos by J.B. Lima.

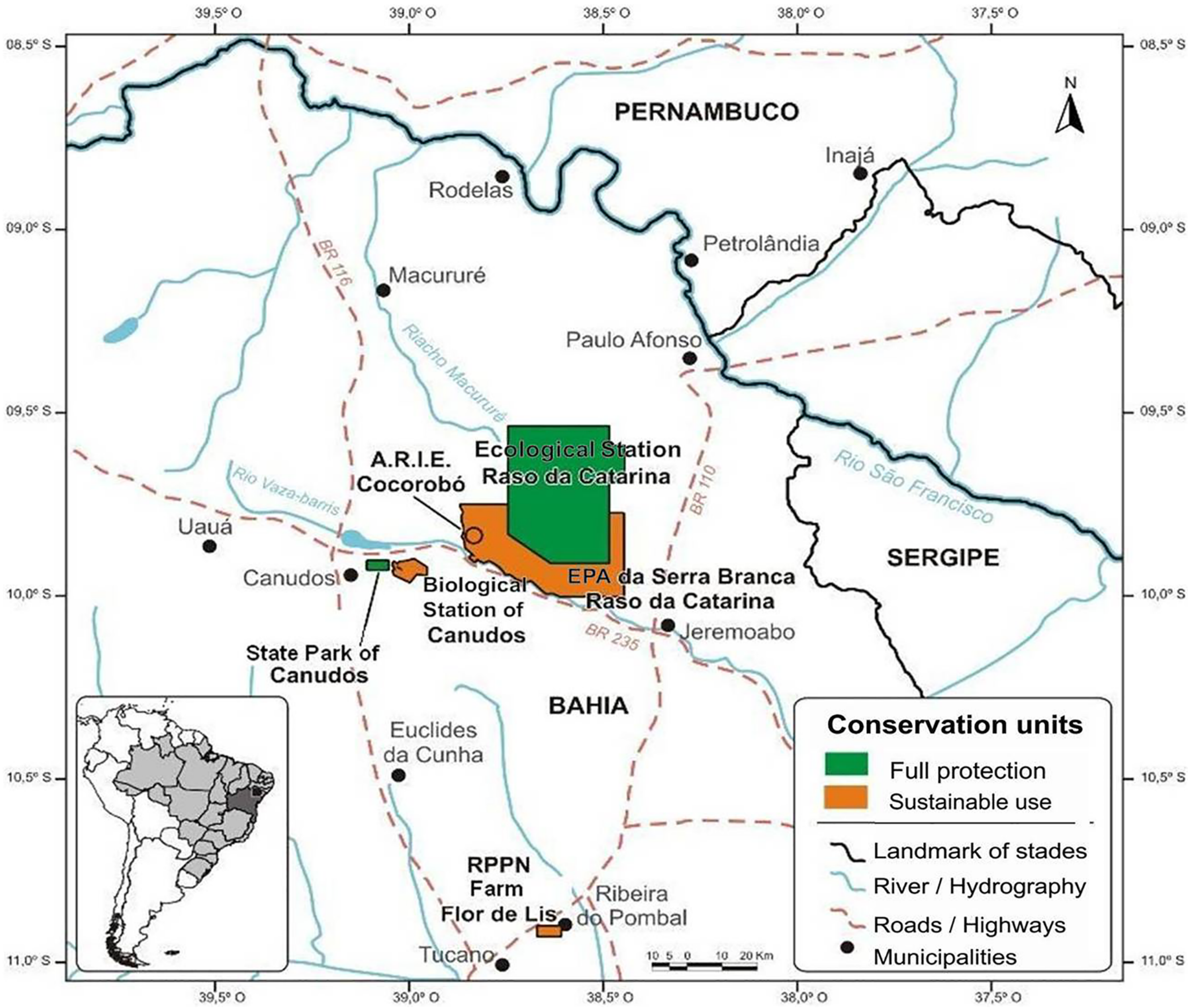

Figure 2. Location of conservation units of the Raso da Catarina Ecoregion, state of Bahia, Brazil (Varjão et al. 2013, modified).

et al. 2002, Gibbs & Semir 2003, Carvalho-Sobrinho 2006, Cristóbal 2006, Duarte 2006, Róndon & Campos 2006, Cruz & Esteves 2009, Rondón 2009 and Carvalho-Sobrinho et al. 2014), protologues and images of type specimens. Morphological descriptions followed Harris & Harris (2001) and Gonçalves & Lorenzi (2011). The taxonomic treatment includes morphological descriptions, an identification key, and comments on distribution, ecology and taxonomy of all studied species.

Results and Discussion

In the RCE, the subfamilies Bombacoideae, Byttnerioideae, Grewioideae and Helicterioideae were represented by a total of 22 species distributed among 10 genera (Figure 3). *Waltheria* L. was the most represented genus with five species, followed by *Ceiba* Mill. and *Melochia* L. with three species each. *Helicteres* L., *Luehea* Willd., *Pachira* Aubl. and *Pseudobombax* Dugand were each represented by two species, while the remaining genera were represented by a single species each. The most frequently encountered species in the study were *Helicteres velutina* K.Schum., *Melochia tomentosa* L., *Waltheria brachypetala* Turcz., *W. indica* L. and *W. rotundifolia* Schrank. These species grow in subshrub and forest Caatinga environments associated with sandy soils, the latter two are also observed in anthropic areas. The species of *Luehea* were rare in RCE, being represented by a single specimen.

Among the species recognized for RCE, nine are endemic to Brazil, *Luehea candicans* Mart. represents a new record for the Caatinga biome. *Pseudobombax parvifolium* Carv.-Sobr. & L.P.Queiroz, *Pseudobombax simplicifolium* A.Robyns, *Waltheria brachypetala* Turcz. and *Ayenia hirta* A.St.-Hil. & Naudin are endemic to the Caatinga, the last of which occurs exclusively in the state of Bahia (Robyns 1963, Carvalho-Sobrinho & Queiroz 2010, Duarte 2015a, b, c, Esteves 2015a, b, c, f). Some species such as *Melochia tomentosa* L., *Waltheria indica* L. and *Luehea paniculata* Mart. have medicinal, agricultural and forage potential. Species of the subfamily Bombacoideae are ornamental and serve in fiber production (Sampaio et al. 2005, Lorenzi & Matos 2008, Kinupp & Lorenzi 2014).

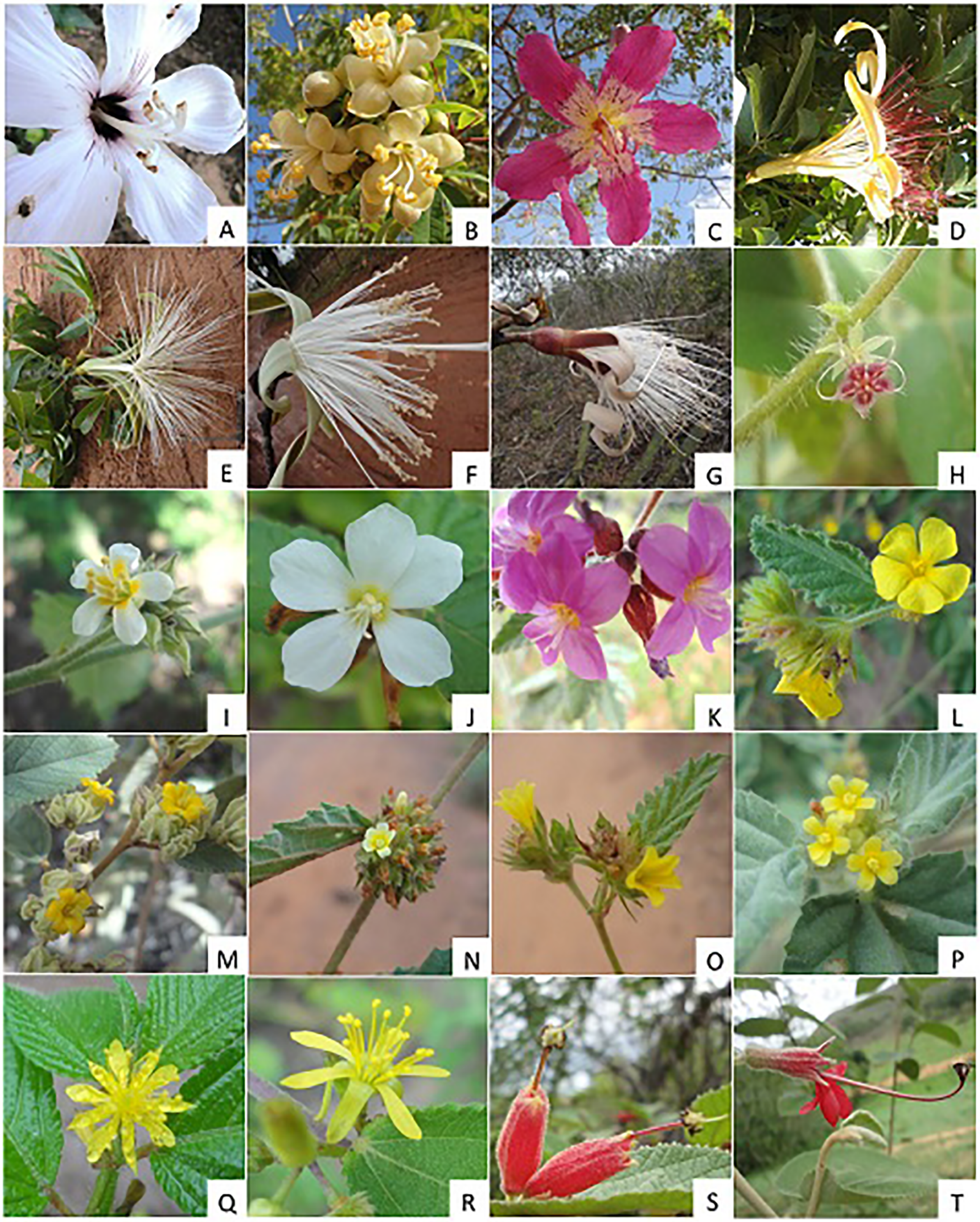

Figure 3. Representatives of the subfamilies Bombacoideae, Byttnerioideae, Grewioideae and Helicterioideae in the Raso da Catarina Ecoregion. A. *Ceiba glaziovii*; B. *Ceiba pentandra*; C. *Ceiba pubiflora*; D. *Pachira aquatica*; E. *Pachira endecaphylla*; F. *Pseudobombax parvifolium*; G. *Pseudobombax simplicifolium*; H. *Ayenia hirta*; I. *Melochia betonicifolia*; J. *Melochia illicioides*; K. *Melochia tomentosa*; L. *Waltheria albicans*; M. *Waltheria brachypetala*; N. *Waltheria indica*; O. *Waltheria operculata*; P. *Waltheria rotundifolia*; Q. *Corchorus hirtus*; R. *Triumfetta semitriloba*; S. *Helicteres eichleri*; T. *Helicteres velutina*. Photos by J.B. Lima.

Identification key to the species of Bombacoideae, Byttnerioideae, Grewioideae and Helicterioideae from RCE, Bahia, Brazil

1\. Trees.

2\. Leaves compound.

3\. Trunk and branches aculeate. Flowers with 5 stamens.

4\. Leaflets with margin entire. Petals without macules ....**1.2. *Ceiba pentandra* (cultivaded)**

4'. Leaflets with margin slightly serrate. Petals with macules.

5\. Petals white, presence of entire appendages at the base of the staminal tube .... **1.1. *Ceiba glaziovii***

5'. Petals lilac to pink, presence of bifid appendages at the base of the staminal tube .... **1.3. *Ceiba pubiflora***

3'. Trunk and branches inerms. Flowers with more than 5 stamens.

6\. Staminal tube bigger than 5 cm long, originating 10 phalanges.

7\. Stamens white at the base and vinaceous on apex. Seeds 25–43×17–22 mm, angulate .... **1.4. *Pachira aquatica* (cultivaded)**

7'. Stamens white. Seeds 6–8×5-6 mm, subglobose .... **1.5. *Pachira endecaphylla***

6'. Staminal tube smaller than 3 cm long, originating free filaments.

8\. Branches without brachyblast. Leaves 5–7 foliolate. Staminal tube pubescent. Capsule 8.5–9×4.5–5 cm, elliptic. Seeds subreniform, brown with inconspicuous macules slightly darker .... **1.6. *Pseudobombax parvifolium***

8'. Branches with brachyblast. Leaves 1(–3) foliolate. Staminal tube glabrous. Capsule 11–13×1.8–2.5 cm, oblong. Seeds piriform to subglobose, light brown, without macules .... **1.7. *Pseudobombax simplicifolium***

2'. Leaves simple.

9\. Solitary flower, terminal .... **3.2. *Luehea candicans***

9'. Inflorescence paniculate, terminal and axillary .... **3.3. *Luehea paniculata***

1'. Subshrub to shrub.

10\. Flowers with 5 stamens.

11\. Ovary with 5-6 locules.

12\. Androgynophore present. Petals with claw that project to a base of the androgynophore and appendages on the blade. Anters 3–thecate. Capsule subglobose, aculeate ...... **2.1. *Ayenia hirta***

12'. Androgynophore absent. Petals flat, not divided into claw and blade without appendages. Anters bitecate. Capsule pyramidal, not aculeate.

13\. Petals white.

14\. Petals up to 8 mm long. Capsule pyramidal .... **2.2. *Melochia betonicifolia***

14'. Petals 12–15 mm long. Capsule conic-globose .... **2.3. *Melochia illicioides***

13'. Petals lilac .... **2.4. *Melochia tomentosa***

11'. Ovary with 1 locule.

15\. Branches with simple trichomes. Inflorescences in helicoidal glomerule, terminal. Capsule with dehiscence operculate .... **2.8. *Waltheria operculata***

15'. Branches with predominantly stellate trichomes. Inflorescences in glomerule not helicoidal, axillary. Capsule with dehiscenceapical, indehiscent or loculicidal.

16\. Branches slightly flexuose, trichomes stellate stipitated. Leaves lanceolate slightly falciform .... **2.6. *Waltheria brachypetala***

16'. Branches not flexuose, trichomes stellate sessile. Leaves ovate, elliptic or orbicular.

17\. Branches with glandular trichomes. Petals 8–10 mm long .... **2.5. *Waltheria albicans***

17'. Branches without glandular trichomes. Petals smaller than 8 mm long.

18\. Leaves ovate-elliptic, not canescent, green discolorous .... **2.7. *Waltheria indica***

18'. Leaves orbicular, canescent, green concolorous .... **2.9. *Waltheria rotundifolia***

10'. Flowers with more than 5 stamens.

19\. Flowers with 10 stamens. Staminodes present. Capsule spirallate.

20\. Branches and leaves tomentose. Pedicel without nectaries. Petals included, reduced to flabeliform claw. Androgynophore erect, 3–4 cm long .... **4.1. *Helicteres eichleri***

20'. Branches and leaves velutinous. Pedicel with 1–3 nectaries. Petals well developed, longer than the calyx. Androgynophore curved, 6–8 cm long .... **4.2. *Helicteres velutina***

19'. Flowers with more than 10 stamens. Staminodes absent. Capsule not spirallate.

21\. Sepals cucullate. Gonophore with glands elliptic at the base of ovary. Nucaceous globose, indehiscent, with uncinate spine .... **3.4. *Triumfetta semitriloba***

21'. Sepals flat. Androgynophore without glands. Capsule elongate-flattened, dehiscence longitudinal, without uncinate spine .... **3.1. *Corchorus hirtus***

Taxonomic Treatment

1. Bombacoideae Burnett

Trees. Leaves compound, venation reticulate. Flowers actinomorphic, hermaphrodite, diclamid or triclamid, solitary or in inflorescence axillary, terminal or oppositifolious. Calyx gamosepalous. Corolla with five petals, free or fused at the base and adnate at the base of staminal tube. Stamens five to numerous, fused at the base, forming a staminal tube. Ovary super; numerous ovules per locule; placentation axile. Fruit capsule.

Consisting of 27 genera and 250 species, Bombacoideae is mainly Neotropical, with some representatives in the tropics of the Old World (Bayer & Kubitzki 2003). In the RCE, the subfamily is represented by three genera and seven species.

1.1. *Ceiba glaziovii* (Kuntze) K.Schum., Bot. Jahresber. (Just) 26(1): 343. 1900. Iconography: Du Bocage & Sales (2002: 126). Figures 3A; 4A-C

Popular name: barriguda.

Tree 6–10 m tall. Trunk tumescent, aculeate, grey, with green longitudinal streaks only in young individuals; branches aculeate;

brachyblast absent. Stipules deciduous, not observed. Leaves alternate-spirallate, digitate, 5 leaflets; petiole 5–10 cm long, glabrous; petiolule 1.5–4 mm long, glabrous; leaflets 2.5–11.5 × 1.5–5.5 cm, elliptic-lanceolate, green, discolorous, membranaceous to chartaceous, base acute, apex acute-acuminate, margin slightly serrate at the apical portion, both surfaces glabrous. Inflorescence cymose, with up to three flowers or sometimes solitary flowers, axillary and terminal; pedicels 1.2–2 cm long., glabrous; bracteoles 3. 3–4 mm long, rounded, green, glabrous, deciduous; calyx 1.5–2 cm long, campanulate, green, 3–5 lobed, apex irregular, externally glabrous, internally glabrous at the base and sericeous at the apex, without glands at the base; petals 1.8–7.5 × 1.8–3.0 cm, obovate, white with macules purple to vinaceous in the base, externally sericeous, internally glabrous on the base and sericeous on the apex; stamens 5, white, fused until half of, staminal tube, 1–3 cm long, glabrous, 5 appendages villous entire at the base of staminal tube, free parts of stamens 2–3 cm long, anthers 4–thecal, white, sinuose, rimose, basifixed; ovary 5–6 × 4–5 mm, subconic, glabrous, 5 locules, numerous ovules per locule; styles 5.6–6 cm long, glabrous, stigmas ellipsoid, rose. Capsule 7–12.5 × 5–8 cm, elliptic, dehiscence longitudinal, glabrous, coriaceous, cotton-fiber white abundant, calyx persistent; seeds 6–7 × 4–6 mm, globose, dark brown, without macules or streaks.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, Trilha do tanque de dentro, 09º51′56.3″S 38º38′41.7″W 469m, 22.VIII.2008, fl., M.V. Romão et al. 268 (HUNEB); Fazenda Serra Branca, 09º53′35.8″S 38º40′27.9″W 404m, 18.IX.2008, fl., M.V. Romão et al. 307 (HUNEB); Fazenda Serra Branca, 09º53′51.5″S 38º40′48.7″W 130m, 30.X.2008, fr., M.V. Romão et al. 387 (HUNEB); Caminho da Judite, próximo a Serra do Navio, 09º51′55.5″S 38º38′45.0″W 469m, 03.XI.2011, fl., J.B. Lima et al. 03 (HUNEB); 04.IX.2012, fl., J.B. Lima et al. 64 (HUNEB); 20.I.2015, fr., J.B. Lima et al. 600 (HUNEB); Povoado Brejinho 10º02′32.0″S 38º21′44.2″W 307m, 31.VII.2014, fl., J.B. Lima et al. 460 (HUNEB); Povoado Brejinho, próximo a casa verde 10º02′26.7″S 38º21′42.9″W 309m, 25.XI.2014,fr., J.B. Lima et al. 573, 576 (HUNEB); Entre Jeremoabo e Canudos, 10º04′07″S 38º28′21″W 297m, 27.VI.2072, bot., R.M. Santos et al. 1664, 1665 (HUEFS); Paulo Afonso, Povoado Arrastapé, 09º30′49.2″S 38º16′55.3″W 300m, 25.IX.2013, fl., J.B. Lima et al. 107 (HUNEB); Povoado Bogó, 09º39′14.5″S 38º16′08.1″W 326m, 01.IX.2014, fl., J.B. Lima et al. 523 (HUNEB); Ribeira do Pombal, Fazenda Cassussu, 10º47′25.7″S 38º34′43.7″W 209m, 09.VIII.2014, fl., J.B. Lima et al. 485 (HUNEB).

Endemic to the Northeast Region of Brazil, *Ceiba glaziovii* occurs only in the states of Bahia, Ceará, Paraíba, Pernambuco, Rio Grande do Norte and Sergipe, in the areas of Caatinga, Cerrado and Atlantic Forest (Gibbs & Semir 2003, Duarte 2015a). In RCE it was collected in the Environmental Protection Area Serra Branca (EPASB), municipality of Jeremoabo, and in the municipalities of Ribeira do Pombal and Tucano, mainly in areas of preserved Caatinga.

The species is recognized by its intumescent trunk; petals white with purple macules and externally villous; and by the presence of five appendages at the base of the staminal tube. It flowers from July to October and fruits from September to November. According to Sampaio et al. (2005), *C. glaziovii* has medicinal, ornamental and apicultural potential.

1.2. *Ceiba pentandra* (L.) Gaertn., Fruct. Sem. Pl. 2: 244. 1791. Figures 3B; 4D-F

Popular names: samaúma, barriguda-falada.

Tree 3–8 m tall. Trunk not tumescent, aculeate, green, with green longitudinal streaks; branches aculeate; brachyblast absent. Stipules deciduous, not observed. Leaves alternate-spirallate, digitate; petiole 3.5–13.9 cm long, glabrous; petiolules 1.5–3 mm long, glabrous; leaflets 5–8, 3.4–12.3 × 1.3–3.4 cm, elliptic-lanceolate, green, discolorous, membranaceous to chartaceous, base acute, apex acuminate, margin entire, both surfaces glabrous. Inflorescence cymose fasciculated, with 5–10 flowers axillary and terminal; pedicels 1.3–3 cm long, glabrous; bracteoles absent; calyx 1–1.3 cm long, campanulate, green, 4–5 lobed, apex irregular, externally glabrous, internally sericeous, without glands at the base; petals 2.5–3 × 1.3–1.7 cm, obovate, white, without macules, externally sericeous, internally glabrous on the base and sericeous on the apex; stamens 5, white, fused at the base, staminal tube ca. 3 mm long, glabrous, without appendages at the staminal tube, free parts of stamens 2–2.3 cm long, anthers 4–thecal, beige, sinuose, rimose, dorsifixed; ovary 5–6 × 3–4 mm, piriform, glabrous, 5 locules, numerous ovules per locule; styles 2–2.5 cm long, glabrous, stigmas ellipsoid, yellow. Capsule 8–13 × 2.8–3.7 cm, elliptic, dehiscence longitudinal, glabrous, coriaceous, cotton-fiber white abundant, calyx persistent; seeds 5–6 × 5–6 mm, globose, blackened, without macules and streaks.

Specimens examined: BRAZIL, BAHIA: Paulo Afonso, Vila Matias, 09º26′56.1″S 38º14′19.0″W 326m, 16.IV.2014, fr., J.B. Lima et al. 301 (HUNEB); Vila Matias, 09º26′56.1″S 38º14′19.0″W 326m, 15.X.2014, fl., J.B. Lima et al. 540 (HUNEB); Praça entre a 1ª cia do exército e o anexo da UNEB, 09º24.235′S 38º12.772′W 215m, 26.VIII.2014, fl.; fr., J.B. Lima et al. 522 (HUNEB); Glória, estrada em direção a orla, 09º20′46.9″S 38º15′24.5″W 273m, fr., J.B. Lima et al. 306 (HUNEB).

With pantropical distribution, *C. pentandra* was possibly introduced in Asia and the Pacific (Gibbs & Semir 2003). In the Brazil it is found in the states of Acre, Pará, Roraima and Maranhão in the areas of Amazon Rainforest (Duarte 2015a). In the RCE the species is only grown in squares and residences of Paulo Afonso and Glória.

The species differs from its congeners in the study area by having 5–8 foliate leaves; fasciculate inflorescence; white petals without macules and measuring less than 5 cm long; and by the absence of appendages at the base of the staminal tube. It was collected with flowers in August and October, and was fruiting throughout almost all year. *Ceiba pentandra* possesses ornamental, apicultural, food and fiber potential (Sampaio et al. 2005, Kinupp & Lorenzi 2014).

1.3. *Ceiba pubiflora* (A.St.-Hil.) K.Schum., Fl. Bras. (Martius) 12(3): 213. 1886. Iconography: Gibbs & Semir (2003: 277), Duarte (2006: 52). Figure 3C

Tree 6–8 m tall. Trunk not tumescent, aculeate, grey, with green longitudinal streaks; branches aculeate; brachyblast absent. Stipules deciduous, not observed. Leaves alternate-spirallate, digitate; petiole 4.8–9.2 cm long, glabrous; petiolules 0.5–1.2 mm long, glabrous; leaflets 5, 3.5–14.8 × 1.1–5.2 cm, elliptic-lanceolate, green, discolorous, membranaceous to chartaceous, base acute, apex acute-acuminate, margin slightly serrate, both surfaces glabrous. Inflorescence cymose, with until 5 flowers, axillary and terminal; pedicels 1.5–2 cm long, glabrous; bracteoles 3, deciduous, 3–5 mm long, ovate, green, glabrous; calyx 1.4–2 cm long, campanulate, green, 3–4 lobed, apex irregular, externally glabrous, internally sericeous on the base and glabrous on the apex, without glands at the base; petals 2.3–8.7 × 1.5–3 cm, obovate to spatulate, lilac to pink with alb base and macules purple to vinaceous, externally sericeous, internally glabrescent on the base and sericeous on the apex; stamens 5, white at the base and pink at apical half, fused until a half of, staminal tube, 1.5–1.8 cm long, glabrous, 5 bifid appendages villous on the base of staminal tube, free parts of stamens 2.8–4.5 cm long, anthers 4–thecal, white, sinuose, rimose, basifixed; ovary 8–10 × 4–5 mm, subconic, glabrous, 5 locules, numerous ovules per locule; styles 5–6 cm long, glabrous, stigmas globose, pink. Fruit not seen.

Specimens examined: BRAZIL, BAHIA: Paulo Afonso, Bairro BNH, próximo a área do erxército, 09º23′38.4″S 38º13′44.9″W 252m, 17.III.2014, fl., J.B. Lima et al. 190 (HUNEB); Povoado Juá, 09º26′22.7″S 38º25′16.7″W 371m, 09.V.2014, fl., J.B. Lima et al. 350 (HUNEB).

Ceiba pubiflora occurs in Argentina (Missiones), Paraguay and Brazil; in Brazil it is present in the Northeast (Bahia), Central-West (Distrito Federal, Goiás, Mato Grosso do Sul, Mato Grosso) and Southeast (Espírito Santo, Minas Gerais, Rio de Janeiro, São Paulo) regions, in environments of Caatinga, Cerrado and Atlantic Forest (Gibbs & Semir 2003, Duarte 2015a). It was introduced in the RCE as an ornamental species.

The species is easily recognized by having flowers with lilac to pink-colored petals with white base and purple to vinaceous macules; and by the presence of five bifid appendages in the base of the staminal tube. It flowers from March to May, and has not been found with fruits.

1.4. *Pachira aquatica* Aubl., Hist. Pl. Guiane 2: 726. 1775. Iconography: Robyns (1963: 235), Du Bocage & Sales (2002: 132). Figure 3D
Popular name: carolina.

Tree 6–14 m tall. Trunk not tumescent, inermous, grey, without green longitudinal streaks; branches inermous; brachyblast absent. Stipules 4–5 mm long, deltoid, deciduous. Leaves alternate-spirallate, digitate; petiole 4.5–14.7 cm long, glabrous; petiolules 0.3–2.0 mm long, glabrous; leaflets 5–7, 5.4–23.5 × 2.1–9.8 cm, oblong-lanceolate to obovate, green, discolorous, semi-coriaceous, base acute, apex acuminate to obtuse, margin entire to slightly sinuose, both surfaces glabrous. Inflorescence cymose 2–3 flowers, usually flowers solitary, axillary and terminal; pedicels 1.5–3 cm long, glabrescent with stellate trichomes, ferruginous; bracteoles 3, deciduous; calyx 1.2–1.8 cm long, campanulate, green, apex truncate, sometimes slightly 4–5 lobed, containing 5 pink glands at the base, externally pubescent, internally sericeous; petals 23–28 × 0.9 × 1.5 cm, linear-lanceolate, intenally white, externally beige to light brown on the margin, both surfaces pubescent; stamens 200-230, white at the base and vinaceous on apex, fused until a half, staminal tube 7–9 cm long, pubescent, tube with two verticil, external verticil divided into 10 phalanges with 1.3–2 cm long, internal verticil divided into 5 phalanges, free parts of stamens 7.5–9 cm long, appendages absent, anthers monothecate, vinaceous, curved, rimoses, dorsifixed; ovary 6–7 × 5–6 mm, piriform, 5 costate, pubescent, 5 locules, numerous ovules per locule; styles 22.5 cm long, pubescent, white with apex pink to purple, stigmas 5 lobed, rose. Capsule 14–19.6 × 9–10 cm, subglobose to oblong-elliptic, dehiscence longitudinal, puberule, woody, without cotton-fiber, calyx not persistent; seeds 25–43 × 17–22 mm, 3–4 angular, white, with streaks.

Specimens examined: BRAZIL, BAHIA: Ribeira do Pombal, alto do Santo Antônio, em direção a PRNH Flor de Lis, 10º50′02.1″S 38º31′32.0″W 241m, 17.I.2014, fl.; fr, J.B. Lima et al. 174 (HUNEB); Canudos, estrada saindo da base 1 da EBC, próximo a casa de Rute e Tiago, 09º54′52.0″S 39º00′28.5″W 459m, 27.III.2014, fl.; fr, J.B. Lima et al. 255 (HUNEB).

Pachira aquatica occurs predominantly in Central and South America (Robyns 1963). In Brazil it is present in the states of Acre, Amazonas, Pará and Maranhão, in the Amazon Rainforest (Duarte 2015b). In the RCE the species is common in the city squares of several municipalities.

The species can be recognized by its flowers having a long stamen tube; external verticil divided into ten phalanges; white stamens with a vinaceous apical half; and by 3–4 angular, striated seeds measuring 25–43×17–22 mm. The species flowers and fruits throughout the year. The species has ornamental, food and fiber potential (Sampaio et al. 2005, Kinupp & Lorenzi 2014).

1.5. *Pachira endecaphylla* (Vell.) Carv.-Sobr., Taxon 62(4): 816. 2013. Iconography: Schumann (1886: 45). Figures 3E; 4G-J

Tree 10-12 m tall. Trunk not tumescent, inermous, green, with green longitudinal streaks inconspicuous; branches inermous; brachyblast absent. Stipules deciduous, not observed. Leaves alternate-spirallate, digitate; petiole 7–15 cm long, glabrous; leaflets 7–10, subsessile, 7–20 × 2–5.8 cm, oblong to lanceolate, green, discolorous, coriaceous, base attenuate decurrent, apex acute-acuminate, margin entire slightly sinuose, both surfaces glabrous. Flowers solitary, axillary, clustered at the apex of branches; pedicels 1–1.5 cm long, glabrescent with trichomes simple, ferruginous, sparse; bracteoles 3, deciduous; calyx 1.2–1.5 cm long, campanulate, green, apex truncate, slightly 5 lobed, containing 5 rose glands at the base, externally glabrescent, internally sericeous; petals 18–20.5 × 1–1.5 cm, linear-lanceolate, beige greenish, both as surfaces pubescent; stamens 125–150, white, fused until a half, staminal tube, 7–9 cm long, pubescent, tube with one verticil, divided into 10 phalanges with 1.5–2 cm long, free parts of stamens 5.2–7.5 cm long, appendages absent, anthers monothecate, beige, linear, rimose, basifixed; ovary 4–5 × 4–5 mm, piriform, not costate, pubescent, 5 locules, numerous ovules per locule; styles 15 cm long, pubescent, white, stigmas 5 lobed, white. Capsule 17–21 × 4.5–5 cm, oblong-elliptic, dehiscence longitudinal, glabrous, woody, cotton-fiber light brown, calyx persistent; seeds 6-8 × 5-6 mm, subglobose, black pits, with 4 streaks beige salient, leaving from the same point.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, estrada do Quelés, próximo a casa de Antônio Rouxinho, 09º57′30.3″S 38º26′20.0″W 504m, 03.IX.2012, fr, J.B. Lima et al. 52 (HUNEB); Povoado Brejinho, 10º02′26.6″S 38º21′42.8″W 308m, 08.III.2014, fl., J.B. Lima et al. 189 (HUNEB); Povoado Brejinho 10º02′32.0″S 38º21′44.2″W 307m, 15.V.2014,fr., J.B. Lima et al. 384 (HUNEB); Povoado Brejinho, próximo a casa verde 10º02′26.7″S 38º21′42.9″W 309m, 25.XI.2014, fr., J.B. Lima et al. 575 (HUNEB).

Endemic to Brazil, *Pachira endecaphylla* is widely distributed in the states of Espírito Santo and Rio de Janeiro, where it occurs in seasonal forest environments. It has also been recorded in the states Alagoas,

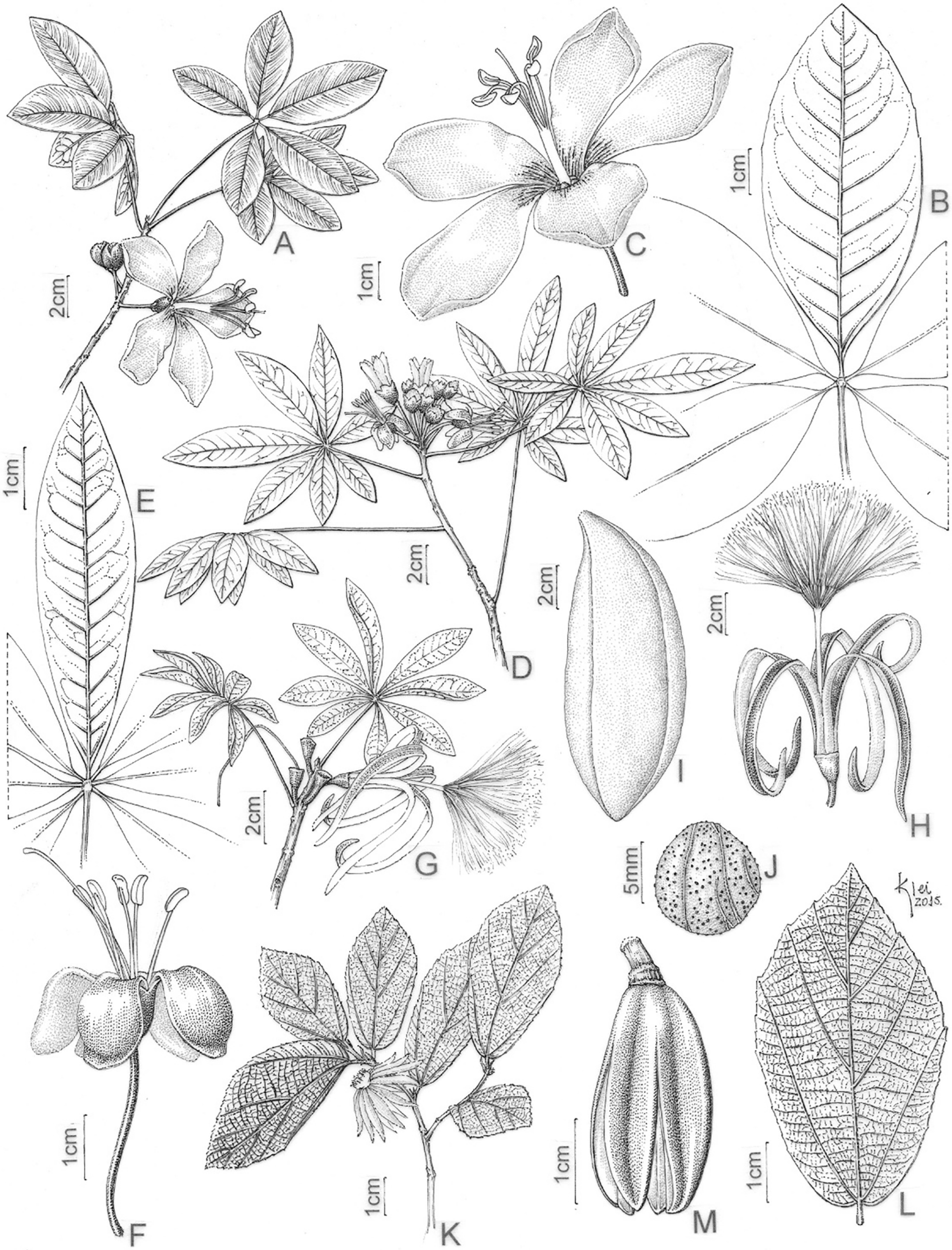

Figure 4. A-C. *Ceiba glaziovii*. A. flowering branch; B. leaflet; C. flower; D-F. *Ceiba pentandra*. D. flowering branch; E. leaflet; F. flower. G-J. *Pachira endecaphylla*. G. flowering branch; H. flower; I. fruit; J. seed. K-M. *Luehea candicans*. K. flowering branch; L. leaf; M. fruit. A-C from J.B. Lima 107; D-F from J.B. Lima 540; G-J from J.B. Lima 189; K-M from J.B. Lima 509.

Bahia, Pernambuco, Rio Grande do Norte, Piauí, Sergipe and Tocantins (Carvalho-Sobrinho et al. 2014, Duarte 2015b). In the RCE the species was encountered only in the municipality of Jeremoabo in an area of anthropized Caatinga.

In the study area, *P. endecaphylla* is characterized by having leaves with 7–10 subsessile, oblong to lanceolate leaflets; flowers with a long tube containing a single verticil; completely white stamens; and subglobose seeds with 4 prominent striae and measuring approximately 8 mm long. It was collected with flowers in March and with fruits in May, June, September and November.

1.6. *Pseudobombax parvifolium* Carv.-Sobr. & L.P.Queiroz, Novon 20(1): 17. 2010. Iconography: Carvalho-Sobrinho (2006: 72), Carvalho-Sobrinho & Queiroz (2010: 18). Figure 3F

Tree 5-7 m tall. Trunk not tumescent, inermous, grey, with green longitudinal streaks; branches inerm; brachyblast absent. Stipules deciduous, not observed. Leaves alternate-spirallate, digitate, clustered at the apex of branches; petiole 4–10 cm long, pubescent to glabrescent; leaflets 5–7, subsessile, 2.5–10.4×2.5–5 cm, oblanceolate to elliptic, green, slightly discolorous, chartaceous, base cuneate to atenuate, apex acute-acuminate, margin entire to slightly crenulate, both surfaces glabrescent with trichomes sparse on vein of abaxial surface. Flowers solitary, terminal, clustered at the apex of branches; pedicels 1.4–2.5 cm long, pubescent to glabrescent with trichomes stellate, ferruginous, sparse; bracteoles 3, deciduous; calyx 1–1.4 cm long, cupuliform to campanulate, dark purple, apex truncate, sometimes slightly 5 apiculate, containing c. 10 glands at the base, externally pubescent, internally sericeous at apical half of; petals 8.5–15×1–1.5 cm, linear-lanceolate, beige to brown, abaxial surface pubescent with trichomes stellate, adaxial surface velutinous being a half with trichomes larger and denser than the other, forming two longitudinal lines; stamens c. 400, white, fused at the base, staminal tube, 1.8–2.2 cm long, pubescent, originating free fillets, free parts of stamens 8–12 cm long, anthers monothecate, white, clavate, rimose, basifixed; ovary 8–10×4–5 mm, ovoid, lightly 5-angulate, subglabrous, 5 locules, numerous ovules per locule; styles 12–16 cm long, subglabrous, white, stigmas 5 lobed, white. Capsule 8.5–9×4.5–5 cm, elliptic, dehiscence longitudinal, glabrous, woody, cotton-fiber light brown, calyx persistent; seeds 5–6×*c.*4 mm, subreniform, brown with macules inconspicuous slightly darker.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, estrada dos Quelés, 09º57′45.8″S 38º26′17.4″W 529m, 05.VI.2012, fr., V.O. Amorim et al. 109 (HUNEB); APA Serra Branca, 09º57′27.7″S 38º26′17.1″W 493m, 12.XI.2013, fl., M.R.R.M. Mazzotti et al. 02 (HUNEB); Fazenda Serra Branca, 09º53′51.5″S 38º40′48.7″W 130m, 30.X.2008, fr., M.V. Romão et al. 386 (HUNEB); Próximo a casa de Antônio Rouxinho, 09º57′27.7″S 38º26′15.8″W 492m, 15.V.2014, fl., J.B. Lima et al. 388 (HUNEB); 19.I.2015, fl., J.B. Lima et al. 596 (HUNEB); Depois do povoado Água Branca, próximo a casa de Maria José, 09º57′13.1″S 38º41′11.7″W 343m, 30.VII.2014, fl., J.B. Lima et al. 451 (HUNEB); 15.X.2014, fl.; fr., J.B. Lima et al. 542 (HUNEB); Fazenda Serra Branca, ao lado da casa principal, 09º57′24.5″S 38º42′22.4″W 328m, 15.X.2014, fr., J.B. Lima et al. 543 (HUNEB); 25.XI.2014, fr., J.B. Lima et al. 577 (HUNEB); Povoado Brejinho, próximo a casa verde 10º02′26.7″S 38º21′42.9″W 309m, 25.XI.2014, fl., J.B. Lima et al. 574 (HUNEB).

Endemic to the Caatinga, it occurs in Northeast Region of Brazil, of the states of Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe, in Southeast only of the state of Minas Gerais (Carvalho-Sobrinho & Queiroz 2010, Duarte 2015c). In the RCE, *P. parvifolium* was collected mainly in the EPASB (Jeremoabo), but also in the municipalities of Paulo Afonso, Tucano and Chorrochó.

Pseudobombax parvifolium can be recognized in the study area by 5-7 foliate leaves; short, pubescent staminal tube with ca. 400 stamens; fruit of c. 5 cm long; and by subreniform seeds with inconspicuous macules. It was collected with flowers in May, July and October to January and with fruits in October and November.

1.7. *Pseudobombax simplicifolium* A.Robyns, Bull. Jard. Bot. État Bruxelles 33: 81. 1963. Iconography: Du Bocage & Sales (2002: 135), Carvalho-Sobrinho (2006: 78). Figure 3G

Tree 6–8 m tall. Trunk not tumescent, inermous, grey, with green longitudinal streaks; branches inermous; brachyblast present. Stipules deciduous, not observed. Leaves alternate-spirallate, clustered at the apex of brachyblast; petiole 0.3–3.4 cm long, glabrous; leaflets 1(–3), sessile, 3.7–8.1×1.5–4 cm, elliptic to ovate-elliptics, green, discolorous, chartaceous, base obtuse, apex acute, margin entire, both surfaces glabrous. Flowers solitary, terminal, at the apex of brachyblast; pedicels 1.7–2 cm long, glabrous; bracteoles 3, triangular ca. 2 mm long; calyx 0.7–1.3 cm long, campanulate, dark purple, apex truncate, containing 5–6 glands at the base; externally glabrous, internally sericeous at the apical half of; petals 7–15×0.8–1.1 cm, linear-lanceolate, beige to brown, abaxial surface pubescent with trichomes stellate, adaxial surface velutinous with trichomes simple and long, and trichomes stellate thin forming a marginal line c. 2 mm larg; stamens 240–350, white, fused at the base, staminal tube, 0.7–1.1 cm long, glabrous, free parts of stamens 5–12 cm long, anthers monothecate, white, clavate, rimose, basifixed; ovary 5–6×3–4 mm, conic, not costate, glabrescent, 5 locules, numerous ovules per locule; styles 12–13.5 cm long, glabrous, white, stigmas 5 lobed, white. Capsule 11–13×1.8–2.5 cm, oblong, dehiscence longitudinal, glabrous, subwoody, cotton-fiber beige brownish, calyx persistent; seeds 5×3 mm, piriform to subglobose, light brown, without macules.

Specimens examined: BRAZIL, BAHIA: Bendengó, estrada sentido Uauá, BR235/Km204, 09º57′08.7″S 39º16′10.9″W 463m, 18.X.2014, fl., J.B. Lima et al. 562 (HUNEB); Uauá, 4 km depois de Uauá, estrada sentido Monte Santo, 09º52′43.4″S 39º29′21.0″W 473m, 18.X.2014, fl.; fr., J.B. Lima et al. 568 (HUNEB); 09º52′51.8″S 39º29′24.4″W 473m, 18.X.2014, fl.; fr., J.B. Lima et al. 569 (HUNEB).

Pseudobombax simplicifolium is endemic to the Caatinga, with records in the west regions of the state of Pernambuco, south region of Piauí, Bahia, Sergipe and Minas Gerais (Robyns 1963, Du Bocage & Sales 2002, Carvalho-Sobrinho 2006, Duarte 2015c). Being an indicator of the Caatinga domain, in the RCE the species was found only in the vicinity of the municipality of Uauá.

The species is recognized by having branches containing brachyblasts; 1(–3) foliate leaves; a short, glabrous staminal tube; fruits up to 2.5 cm in length; and seeds without macules. It was found in RCE with flowers in August and October and fruits in October. It is noteworthy for its wood and fiber production potential (Sampaio et al. 2005).

2. Byttnerioideae Burnett

Subshrubs to shrubs. Leaves simple, entires, venation palmately. Flowers actinomorphic, bissexual, diclamid, solitary or usually in inflorescence axillary or terminal. Calyx gamosepalous with 5 lobes. Corolla with 5 petals, fused in the base of staminal tube. Stamens 5, fused at the base, forming a staminal tube, with or without androgynophore, anthers rimose, dorsifixed. Ovary super; one ovule per locule, placentation axile. Fruit capsule.

Consisting of 26 genera and 650 species, Byttnerioideae occurs in the tropics of the New and Old World (Bayer & Kubitzki 2003). In the RCE it is represented by three genera and nine species.

2.1. ***Ayenia hirta*** A.St.-Hil. & Naudin, Ann. Sci. Nat., Bot. sér. 2, 18: 34. 1842. Iconography: Cristóbal (1960: 161). Figures 3H; 5H-K

Subshrubs 30–50 cm tall; branches cylindrical, not flexuose, hisute-tomentose, trichomes stellate sessile and simple sparse. Stipules linear 1–1.5 mm long, trichomes simple. Leaves alternate-spirallate; petiole 2–5 mm long, trichomes equal to branches; leaf blades 0.7–2.5 × 0.3–1.1 cm, ovate to elliptic, green, discolorous, chartaceous, base rounded to subchordate, apex acute, margin serrate, both surfaces tomentose, with trichomes stellate, more dense at the abaxial surface. Inflorescence cymose 3–5–flowers; pedicels 1–2 mm long; bracteoles absent; calyx 2–2.5 mm long, lobes with apex triangular, externally with trichomes stellate, internally with trichomes glandular; petals rose to purple, claw 3–3.8 mm long, glabrous, connecting the base of the androgynophore, blade 1–1.2 × 1–1.2 mm, pilose; androgynophore 1.5–1.8 mm long, staminal tube, 0.5–0.6 mm long, free parts of stamens c. 0.2 mm long; free parts of staminodes c. 0.3 mm long, anthers 3–thecate; ovary c. 0.5 × 0,5 mm, globose, papilate, 5 locules, 2 ovules per locule; styles 0.2–0.3 mm long, stigmas capitate. Capsule 4–5 × 5–6 mm; subglobose, dehiscence loculicidal, aculeus with trichomes stellate and simple, ferrugineous; seeds 2.5–3 × *1.8*-2 mm, dark brownish to blackened, tuberculate, glabrous.

Specimens examined: BRAZIL, BAHIA: Banzaê, povoado Salgado, estrada do pau branco, 10º35′55.0″S 38º41′56.0″W 306m, 15.I.2014, fr., J.B. Lima et al. 157 (HUNEB); Povoado Serrota, 09º23′19.1″S 38º27′19.4″W 403m, 23.IV.2014, fl.; fr., J.B. Lima et al. 311 (HUNEB); J.V. Santos et al. 292 (HUNEB); L.R. Silva et al. 285 (HUNEB); Paulo Afonso, saindo do Arrastapé em direção a ESEC, 09º34′32.6″S 38º19′28.5″W 373m, 06.V.2014, fl.; fr., J.B. Lima et al. 318 (HUNEB); Estação Ecológica Raso da Catarina, próximo a base nova (3), 09º34′51.5″S 38º29′27.8″W 622m, 22.VII.2014, fl.; fr., J.B. Lima et al. 449 (HUNEB); 03.IX.2014, fl.; fr., J.B. Lima et al. 538 (HUNEB); Jeremoabo, Olho d'água dos negros, 10º01′11.7″S 38º22′08.7″W 432m, 5.VI.2014, fl.; fr., J.B. Lima et al. 408 (HUNEB); Cícero Dantas, Fazenda Pombos, sentido boqueirão, 10º34′37.3″S 38º23′47.4″W 403m, 04.VIII.2014, fl.; fr., J.B. Lima et al. 480 (HUNEB); Estrada do Sapé 10º19′28.5″S 38º35′42.8″W 614m, 05.VIII.2014, fl.; fr., J.B. Lima et al. 490 (HUNEB).

Endemic to the Caatinga in the state of Bahia, Northeast Region of Brazil, *Ayenia hirta* (Cristóbal 1960, Esteves 2015a). Widely distributed in the RCE, the species is common on roadsides.

Ayenia hirta can be recognized by hirsute branches; flowers measuring less than 1 cm; purple petals containing claw that bind to the base of the androgynophore; presence of 3-thecate anthers; and by aculeate fruits with loculicidal dehiscence. It was found with flowers and fruits throughout the year.

2.2. ***Melochia betonicifolia*** A.St.-Hil., Fl. Bras. Merid. 1(4): 165. 1825. Iconography: Cristóbal (2006: 109), Gonçalez & Esteves (2017: 444). Figure 3I

Subshrubs c. 1.30 m tall; branches cylindrical, not flexuose, tomentose, trichomes stellate sessile. Stipules 3–5 mm long, linear, trichomes simple and stellate. Leaves alternate-spirallate; petiole 5–30 mm long, trichomes equal to branches; leaf blades 2.7–10.5 × 1.4–5.4 cm, ovate, green, discolorous, chartaceous, base rounded to truncate, apex acute, margin crenate, both surfaces pubescent, with trichomes stellate, more dense at the abaxial surface. Inflorescence cymose, umbeliform, oppositifolious terminal; pedicels 4–7 mm long; bracteoles absent; calyx 5–7 mm long, campanulate, green, lobes with apex lanceolate-acuminate, externally with trichomes stellate, internally glabrous; petals flat, 7–8 × c.2 mm, spatulate, white with yellow base, glabrous, appendages absent; androgynophore absent; staminal tube c. 1.5 mm long, free parts of stamens 7–8 mm long in brevistylous flowers, anthers dithecate; ovary 2–3 × *c.*1 mm, elliptic, hirsute at apex, 5 locules, 2 ovules per locule; styles 2–3 mm long in brevistylous flowers, longistylous flowers not observed, stigmas papilate. Capsule 0.7–1.5 × 1–2 cm, pyramidal, dehiscence loculicidal, tomentose, trichomes stellate, aculeus absent; seeds 1.5 × 0.5 mm, ellipsoid, light brown, glabrous.

Specimens examined: BRAZIL, BAHIA: Cícero Dantas, boqueirão, em frente a casa de Jorge, 10º33′21.1″S 38º24′29″W 406m, 04.VIII.2014, fl.; fr., J.B. Lima et al. 476 (HUNEB). Euclides da Cunha, estrada em direção ao pai João André, Bela Vista, 10º30′35.3″S 39º01′11.2″W 253m, 18.III.2015, fl.; fr., J.B. Lima et al. 610 (HUNEB).

Endemic to Brazil, *Melochia betonicifolia* occurs in the Northeast (Bahia, Ceará, Pernambuco) and Southeast (Minas Gerais, Rio de Janeiro) regions, in Caatinga, Cerrado and Atlantic Forest (Cristóbal 2006, Gonçalez 2013, Gonçalez 2018). It was few found in the RCE, where the species was found in areas of anthropized Caatinga.

Melochia betonicifolia differs from its congeners by having a white corolla with a yellow base measuring less than 1 cm long, and associated with the presence of pyramidal fruits. It was collected with flowers and fruits in March and August.

2.3. ***Melochia illicioides*** K.Schum., Fl. Bras. (Martius) 12(3): 31. 1886. Figures 3J; 5L-N

Subshrubs c. 1.8 m tall; branches cylindrical, not flexuose, tomentose, trichomes stellate sessile. Stipules c. 2 mm long, linear, trichomes simple and stellate. Leaves alternate-spirallate; petiole 5–17 mm long, trichomes equal to branches; leaf blades 2.5–7 × 1.5–4 cm, ovate to elliptic, green, discolorous, membranaceous, base rouded to subchordate, apex acute, margin crenate, both surfaces pubescent, trichomes stellate, more dense at the abaxial surface. Inflorescence cymose, umbeliform, oppositifolious terminal; pedicels 6–8 mm long; bracteoles absent; calyx 5–8 mm long, campanulate, green-vinaceous, lobes with apex lanceolate-acuminate, externally with trichomes stellate, internally trichomes only at apex; petals flat, 12–15 × c.5 mm,

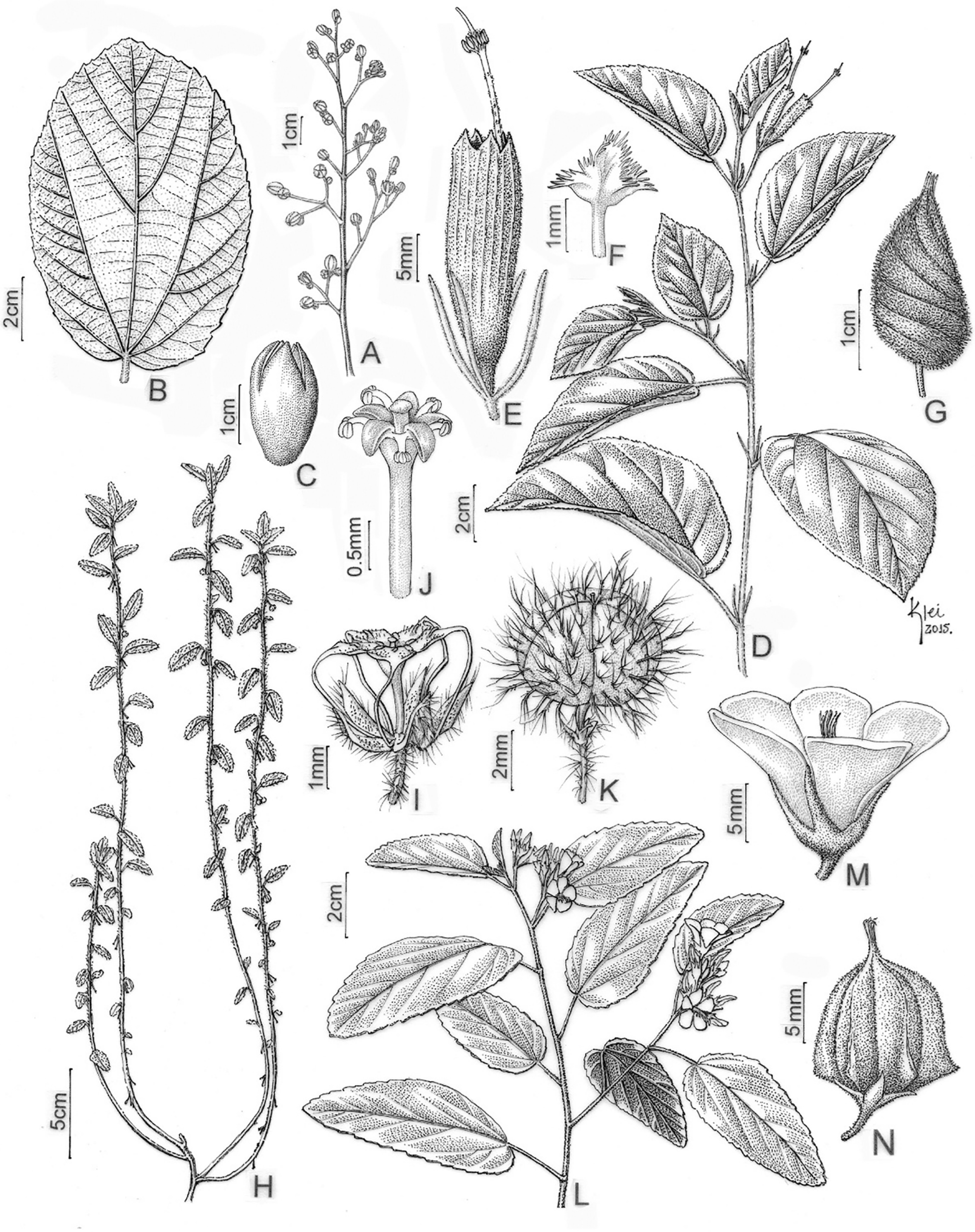

Figure 5. A-C. *Luehea paniculata*. A. inflorescence; B. leaf; C. fruit; D-G. *Helicteres eichleri*. D. flowering branch; E. flower and linear profiles; F. petal; G. fruit. H-K. *Ayenia hirta*. H. flowering branch; I. flower; J. androgynophore; K. fruit. L-N. *Melochia illicioides*. L. flowering branch; M. flower; N. fruit. A-C. from J.B. Lima 492; D-G from J.B. Lima 578; H-K from J.B. Lima 490; L-N from R.R. Varjão 30.

obovate to spatulate, white with yellow base, glabrous, appendages absent; androgynophore absent, staminal tube, c. 1.5 mm long, free parts of stamens 6–10 mm long in brevistylous flowers, 4–6.5 mm long in longistylous flowers, anthers dithecate, yellow; ovary c. 3×2 mm, ovate-elliptic, hirsute at apex, 5–6 locules, 2 ovules per locule; styles 3–5 mm long in brevistylous flowers, 6–9 mm long in longistylous flowers, trichomes stellate, stigmas papilate. Capsule 1–1.7×0.7–1.8 cm, pyramidal, conic-globose, dehiscence loculicidal, tomentose, trichomes stellate, aculeus absent; seeds 1.5–2×0.5–1 mm, ellipsoid, ligth brown, glabrescent.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, estrada da ESEC aos Quelés, 09º56′56.6″S 38º27′04″W 586m, 27.I.2011, fl.; fr, R.R. Varjão et al. 30 (HUNEB); Estrada secundária que dá acesso a ESEC, 09º56′36.6″S 38º27′27.2″W 558m, 11.VII.2012, fl.; fr, J.B. Lima et al. 43 (HUNEB); 09º56′37.3″S 38º27′05.3″W 510m, 20.X.2013, fl.; fr, J.B. Lima et al. 129, 131 (HUNEB).

Melochia illicioides is known only from the city of Honda, in Colombia, and the state of Bahia, in Brazil, where it grows among Atlantic Forest and Cerrado vegetation (Goldberg 1967, Gonçalez 2018). It is treated here as a new occurrence for the Caatinga. In the RCE the species was found only in the EPASB.

In the RCE, *M. illicioides* can be recognized by its white corolla of 12–15 mm in length and by its pyramidal, conic-globose, fruit. It flowers and fruits throughout the year.

2.4. *Melochia tomentosa* L., Syst. Nat., ed. 10. 2: 1140. 1759. Iconography: Rondón & Campos (2006: 149), Rondón (2007: 134, 2009: 54). Figure 3K

Subshrubs 1-1.30 m tall; branches cylindrical, not flexuose, pubescent, trichomes stellate sessile. Stipules 2–3 mm long, linear, trichomes equal to branches. Leaves alternate-spiralate; petiole 1.5–5 mm long, tomentose; leaf blades 0.8–3.5×0.5–2.5 cm, ovate to elliptic, green, discolorous, chartaceous, base obtuse to subchordate, apex retuse, margin crenate-serrate, both surfaces tomentose, trichomes stellate. Inflorescence cymose, umbeliform, axillary and terminal; pedicels 5–7 mm long; bracteoles absent; calyx 5–7 mm long, campanulate, green-vinaceous, lobes with apex acuminate, externally with trichomes stellate, internally trichomes only at the apex; petals flat, 8–10×5–7 mm, obovate, lilac with yellow base, glabrous, appendages absent; androgynophore absent; staminal tube c. 1.5 mm long, free parts of stamens 6–12 mm long in brevistylous flowers, 5–7 mm long in longistylous flowers, anthers dithecate; ovary c. 2×1 mm, ellipsoid, tomentose at the apex, 5 locules, 2 ovules per locule; styles 3–5.2 mm long in brevistylous flowers, 6-8 mm long in longistylous flowers, trichomes stellate in both forms, stigmas papilate. Capsule 0.8-1×0.8-1 cm, pyramidal, dehiscence loculicidal, tomentose, trichomes stellate, aculeus absent; seeds c. 2.1×1.5 mm, ellipsoid, dark brown, glabrous.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, próximo ao barreiro, 09º52′46.5″S 38º40′00.9″W 472m, 24.I.2013, fl., V.O. Amorim et al. 209 (HUNEB); Fazenda Serra Branca, tanque de dentro, 09º51′55.6″S 38º38′45.2″W 156m, 30.X.2008, fl., M.V. Romão et al. 390 (HUNEB); Caminho da Judite, próximo a serra do navio, 09º51′55.5″S 38º38′45″W 469m, 03.XI.2011, fl.; fr., J.B. Lima et al. 02, 04 (HUNEB); Estrada em direção a serra do navio, após o dedo de Deus, 09º52′43.4″S 38º39′14.5″W 463m, 11.II.2014, fl.; fr., J.B. Lima et al. 188 (HUNEB); Roça velha, perto do currau, 09º56′45.1″S 38º42′12.6″W 335m, 30.VII.2014, fl.; fr., J.B. Lima et al. 452 (HUNEB); Canudos, Parque Estadual de Canudos, próximo ao açude Cócorobo, 09º55′03.6″S 39º06′19.6″W 376m, 20.IV.2008, fl., C.L.S.B. Correia et al. 12 (HUNEB); Alto do Mário, 09º55′07.6″S 39º06′36.6″W 388m, 11.X.2008, fl., C.L.S.B. Correia et al. 49 (HUNEB); Alto da favela, 09º54′59.9″S 39º07′01.6″W 401m, 22.III.2008, fl.; fr., M.V. Romão et al. 27 (HUNEB); 10.V.2008, fl.; fr., M.V. Romão et al. 160 (HUNEB); Fazenda velha, 09º54′44.2″S 39º07′17.8″W 366m, 21.IX.2008, fl.; fr., M.V. Romão et al. 344 (HUNEB); Vale da morte, 09º55′11″S 39º07′01.1″W 376m, 15.X.2014, fl.; fr., J.B. Lima et al. 544 (HUNEB); Estação Biológica de Canudos, 09º56′41.1″S 39º00′55.7″W 443m, 27.III.2014, fl.; fr., J.B. Lima et al. 256 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, Base velha (petrobras), 09º43′52.6″S 38º40′57.1″W 601m, 16.IV.2014, fl.; fr., J.B. Lima et al. 296, 299 (HUNEB); 02.IX.2014, fl.; fr., J.B. Lima et al. 525 (HUNEB); Povoado Arrastapé, 09º30′49.2″S 38º16′55.3″W 300m, 20.III.2014, fl.; fr., J.B. Lima et al. 216 (HUNEB); Povoado Barrinha, 09º35′11.2″S 38º19′32.2″W 404m, 6.V.2014, fl.; fr., J.B. Lima et al. 322 (HUNEB); Macururé, saída em direção a Chorrochó, 09º09′02″S 39º03′31″W 361m, 2.VI.2014, fl.; fr., J.B. Lima et al. 396 (HUNEB).

It is distributed in the Americas, including Florida, Mexico, Honduras, Nicaragua, Bahamas, Cuba, Haití, Dominican Republic, Jamaica, Curaçao, Puerto Rico, Trinidad, Colombia, Venezuela and Brazil (Rondón 2007, 2009). In Brazil, *Melochia tomentosa* is found in the Northeast (Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí) and Central-West (Mato Grosso do Sul, Mato Grosso) regions, in a variety of environments such as Caatinga, Cerrado and Atlantic Forest (Gonçalez 2018). The species is widely distributed in the RCE, both in preserved and anthropized areas.

The species can be recognized by its lilac-colored corolla with a yellow base and its axillary umbelliform inflorescence. It was found with flowers and fruits in all months of the year. It possesses medicinal, apicultural and forage potential (Rondón 2009, Sampaio et al. 2005).

2.5. *Waltheria albicans* Turcz., Bull. Soc. Imp. Naturalistes Moscou 31(1): 214. 1858. Iconography: Cristóbal (2006: 112), Rondón (2008: 14). Figures 3L; 6A-E

Subshrubs 70-80 cm tall; branches cylindrical, not flexuose, tomentose, trichomes glandular and stellate sessile. Stipules 3–5 mm long, narrow-triangular, trichomes equal to branches. Leaves alternate-spirallate; petiole 5–22 mm long, tomentose; leaf blades 2.1–6×1.2–4.9 cm, ovate to orbicular, green slightly canescent, discolorous, chartaceous, base obtuse to subchordate, apex rouded, margin dentate to serrate, both surfaces tomentose, trichomes stellate more dense on abaxial surface. Inflorescence cymose in glomerule, axillary and terminal; pedicels 1–2 mm long; bracteoles 4, 5–6 mm long., linear-lanceolate, green, trichomes simple; calyx 6 mm long, campanulate, green, lobes with apex acuminate, externally sericeous, with trichomes simple, internally with trichomes only at the apex; petals flat, 8–10×3–5 mm, obdeltoid, yellow, trichomes simple internally, appendages absent; androgynophore absent; staminal tube c. 1 mm long, free portion of stamens c. 5 mm long, in brevistylous flowers, anthers dithecate; ovary c. 1×0.5 mm, ovoid to elipsoid, sericeous, 1 locule, 1 ovule per locule; styles c. 1 mm long in brevistylous flowers, trichomes simple sparse,

Figure 6. A-D. *Waltheria albicans*. A. flowering branch; B. detail of branch indumentum; C. flower; D. petal; E-H. *Waltheria brachypetala*. E. flowering branch; F. detail of branch indumentum; G. flower; H. petal; I-M. *Waltheria operculata*. I. flowering branch; J. detail of branch indumentum; K. flower; L. petal; M. fruit; N-Q. *Waltheria rotundifolia*. N. flowering branch and detail of branch indumentum; O. flower; P. petal; Q. fruit. A-D from J.B. Lima 392; E-H from J.B. Lima 371; I-M from J.B. Lima 447; N-Q from J.B. Lima 397.

form longistylous not observed, stigmas ciliated. Capsule c. 4×2 mm, obovate, dehiscence loculicidal, trichomes simple, aculeus absent; seeds c. 3×2 mm, obovoid, brownish, glabrous.

Specimens examined: BRAZIL, BAHIA: Macururé, povoado Salgado do melão, próximo ao posto de saúde, 09º17′51.7″S 38º41′24.8″W 422m, 02.VI.2014, fl.; fr., J.B. Lima et al. 392 (HUNEB); Jeremoabo, APA Serra Branca, estrada principal em direção a ESEC, 09º57′12.1″S 38º26′33.7″W 513m, 19.XII.2013, fl.; fr., J.B. Lima et al. 127 (HUNEB); Baixa da forra, perto da roça do Sr. Antônio Roxinho, 09º57′16.1″S 38º26′23.2″W 505m, 19.XII.2013, fl.; fr., T.D.C. Batista et al. 31 (HUNEB).

Waltheria albicans is distributed in Argentina, Brazil, Bolivia, Colombia, Guiana, Mexico, Paraguay and Venezuela (Cristóbal 1998, Rondón 2008). In Brazil it is found in the Amazon Rainforest, Caatinga and Cerrado. In the Northeast Region it is distributed among the states of Bahia, Ceará, Maranhão, Pernambuco and Piauí (Esteves 2015b). It was few found in the RCE, where the species was found in an open field.

In the RCE, the species can be recognized by an indumentum with two branches with glandular trichomes and obdeltoid petals reaching 10 mm in length. It was found with flowers and fruits throughout the year.

2.6. *Waltheria brachypetala* Turcz., Bull. Soc. Imp. Naturalistes Moscou 31(1): 215. 1858. Figures 3M; 6F-J

Popular name: malva-preta.

Shrubs 1.5-2 m tall; branches cylindrical, flexuose, tomentose, trichomes stellate stipitated. Stipules c. 6 mm long, linear, trichomes equal to branches. Leaves alternate-spirallate; petiole 4–7 mm long, tomentose; leaf blades 3.5–7×1.2–2.5 cm, lanceolate slightly falciform, green canescent, concolor, chartaceous, base obtuse to rounded, apex acuminate, margin dentate, both surfaces tomentose, trichomes stellate. Inflorescence cymose in glomerule, axillary, bracts c. 6 mm long, filiform, tomentose; pedicels 1–2 mm long; bracteoles 3, c. 5.5×3.5 mm, elliptic, sericeous; calyx c. 5 mm long, campanulate, green, lobes with apex acute, externally with trichomes stellate, internally glabrous; petals flat, c. 6×4 mm, spatulate, yellow, glabrous; androgynophore absent, staminal tube c. 1.8–2 mm long in brevistylous flowers, 2–3.5 mm long in longistylous flowers, free portion of stamens c. 0.5 mm, anthers dithecate, yellow; ovary c. 0.8×3.5 mm, ellipsoid, velutinous, 1 locule, 1 ovule per locule; styles 1–1.8 mm long in brevistylous flowers, 4–5.2 mm long in longistylous flowers, stigmas plumose. Capsule c. 3×2 mm, ellipsoid, dehiscence apical, trichomes stellate, aculeus absent; seeds 2–2.5×1.3–1.7 mm, obovoid, brownish, glabrous.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, estrada saíndo dos Quelés sentido ESEC, 09º56′45.7″S 38º27′30.1″W 607m, 29.VII.2009, fl., T.M. Silva et al. 145 (HUNEB); Caminho perto de Quelés, 09º54′16.8″S 38º29′33.5″W 605m, 08.IX.2009, fl.; fr., M.V. Romão et al. 526 (HUNEB); Estrada secundária sentido ESEC, 09º56′36.6″S 38º27′27.2″W 558m, 11.VII.2012, fl.; fr., J.B. Lima et al. 42 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, trilha sentido mata da Pororoca, 09º44′37.4″S 38º29′28.8″W 648m, 24.IX.2013, fl., J.B. Lima et al. 103 (HUNEB); Caminho para a base velha da petrobrás, 09º39′02.4″S 38º29′38.1″W 621m, 16.IV.2014, fl.; fr., J.B. Lima et al. 286 (HUNEB); Base velha (petrobras), 09º43′52.6″S 38º40′57.1″W 601m, 10.VI.2014, fl.; fr., J.B. Lima et al. 424 (HUNEB); 02.IX.2014, fl.; fr., J.B. Lima et al. 530 (HUNEB); Trilha sentido sul da estação, ca. de 10 km da mata da Pororoca, 09º52′19.2″S 38º29′31.4″W 629m, 08.IX.2011, fl., C.L.S.B. Correia et al. 562 (HUNEB); Próximo a casa 2 do ICMBio, trilha da baixa da cascavel, 09º44′176″S 38º40′967″W 593m, 26.IX.2011, fl., C.L.S.B. Correia et al. 576 (HUNEB); Canudos, Estação Biológica de Canudos, trilha para o saco das araras, 09º58′26.6″S 38º59′42.1″W 566m, 26.III.2014, fl., J.B. Lima et al. 222 (HUNEB); Baixada depois da base 2, caminho para base 1, 09º56′46.4″S 39º00′42.7″W 433m, 26.III.2014, fl.; fr., J.B. Lima et al. 224 (HUNEB); Caminho da lagoa dos Manezão, 09º56′47.7″S 39º00′43.2″W 421m, 13.V.2014, fl.; fr., J.B. Lima et al. 371 (HUNEB); Saco do gavião, 09º57′16.4″S 39º00′13.6″W 422m, 14.V.2014, fl.; fr., J.B. Lima et al. 378 (HUNEB); Baixada depois da base 2, trilha em direção aos sacos das araras, 09º56′46.3″S 39º00′33.4″W 425m, 16.X.2014, fl.; fr., J.B. Lima et al. 551 (HUNEB); Quinjingue, povoado Tanque do rumo, 10º43′52.2″S 38º54′13.2″W 343m, 06.VIII.2014, fl., J.B. Lima et al. 501 (HUNEB).

Endemic to Caatinga of the Northeastern Brazil, *Waltheria brachypetala* is recorded from the states of Bahia, Ceará, Pernambuco and Piauí. Is considered an indicator of this environment (Amorim et al. 2009, Esteves 2015b). It is widely distributed in the RCE, and can be found forming dense populations in conservation units.

Waltheria brachypetala is recognized by flexuous branches with stellate stipitate trichomes; lanceolate, slightly falciform leaves; and sericeous bracts and calyces. It flowers and fruits throughout the year.

2.7. *Waltheria indica* L., Sp. Pl. 2: 673. 1753. Iconography: Cristóbal (2006: 112), Rondón & Campos (2006: 150), Cruz (2007: 69), Rondón (2008: 24). Figure 3N

Subshrubs 0.5–1.30 m tall; branches cylindrical, not flexuose, pubescent, trichomes simple and stellate sessile. Stipules 3–5 mm long, lanceolate, trichomes equal to branches. Leaves alternate-spirallate; petiole 0.6–2 cm long, pubescent; leaf blades 1.5–6.5×1–3 cm, ovate-elliptic, green not canescent, discolorous, chartaceous, base obtuse, apex acute, margin serrate, both surfaces pubescent, trichomes simple and stellate. Inflorescence cymose in glomerule dense, axillary; pedicels 1–2 mm long; bracteoles 3–4, c. 4–6 mm long, lanceolate, green, trichomes simple; calyx 4–5 mm long, campanulate, light green, lobes with apex acuminate, externally pubescent, with trichomes simple, internally with trichomes only to apex; petals flat, 4–6×0.5–1 mm, spatulate, yellow, trichomes simple at apex; staminal tube c. 2 mm long, free portion of stamens c. 0.5 mm long, anthers dithecate, yellow; ovary c. 1×*0.5* mm, ovoid to elipsoid, sericeous, 1 locule, 2 ovules per locule; styles c. 1.5 mm long, with trichomes stellate, stigmas plumose. Capsule c. 3×2 mm, obovate, indehiscent, trichomes simple at apical portion, aculeus absent; seeds c. 2.5×1.6 mm, obovoid, brownish, glabrous.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, Fazenda Serra Branca, a 9,5 km de distância da base da APA, baixão do araçá, 09º53′08.6″S 38º38′02.3″W 595m, 08.V.2008, fl.; fr., M.V. Romão et al. 138 (HUNEB); Base do ICMBio, 09º55′17.3″S 38º42′06″W 334m, 20.XII.2011, fl.; fr., J.B. Lima et al. 20 (HUNEB); Jeremoabo, 10º15′S 38º34′W, 29.X.1981, fl.; fr., R.P. Orlandi 570 (HRB, RB); Canudos, Estação biológica de Canudos, proximidades da base 02, 09º56′41.1″S 39º00′55.7″W 443m, 26.III.2014, fl.; fr., J.B. Lima et al. 227 (HUNEB); Lagoa dos Manezão, 09º56′58.2″S 39º00′55.1″W 435m, 17.X.2014, fl.; fr., J.B. Lima et al. 561 (HUNEB); Parque Estadual de Canudos, Vale da morte, 09º55′11″S 39º07′01.1″W 376m, 15.X.2014, fl.; fr., J.B. Lima et al. 549 (HUNEB); Paulo Afonso, Estação Ecológica Raso da

Catarina, Base velha da Petrobrás, 09º43′59.7″S 38º40′56.3″W 598m, 19.III.2014, fl.; fr., J.B. Lima et al. 210, 213 (HUNEB); Estrada sentido a base velha, próximo ao barreiro, 09º39′01.1″S 38º34′33.5″W 586m, 16.IV.2014, fl.; fr., J.B. Lima et al. 293 (HUNEB); Proximidades da base velha, 09º43′52.6″S 38º40′57.1″W 601m, 10.VI.2014, fl.; fr., J.B. Lima et al. 423 (HUNEB); 02.IX.2014, fl.; fr., J.B. Lima et al. 526 (HUNEB); Povoado barrinha, 09º35′11.2″S 38º19′32.2″W 404m, 6.V.2014, fl.; fr., J.B. Lima et al. 320, 323 (HUNEB); Cícero Dantas, Fazenda Pombos, sentido boqueirão, 10º34′37.3″S 38º23′47.4″W 403m, 04.VIII.2014, fl.; fr., J.B. Lima et al. 482 (HUNEB); Estrada do sapé, 10º19′32.5″S 38º35′26.2″W 622m, 05.VIII.2014, fl.; fr., J.B. Lima et al. 495 (HUNEB); Cícero Dantas, 10º36′S 39º23′W, 18.VIII.2003, fl.; fr., M.L. Guedes et al. 10559 (ALCB); Euclides da Cunha, Fazenda Binjé, do Sr. Alan, 10º34′07.4″S 39º01′01.8″W 462m, 07.VIII.2014, fl.; fr., J.B. Lima et al. 504 (HUNEB); Banzaê, povoado Salgado, estrada do pau branco, 10º35′55″S 38º41′56″W 306m, 15.I.2014, fl., J.B. Lima et al. 158 (HUNEB).

The only species of the genus with a Pantropical distribution, *Waltheria indica* is present in all of the states and phytogeographic dominions of Brazil (Saunders 1995, Esteves 2015b). It is widely distributed in the ecoregion, and is a common species of anthropized areas.

Waltheria indica is recognized by oval-elliptical discolorous leaves and dense inflorescences. According to Cruz (2007), this species exhibits great morphological variability, although it has homostylous flowers, which is a rare character for the genus. It flowers and fruits throughout the year. It possesses medicinal and apicultural potential (Lorenzi & Matos 2008, Sampaio et al. 2005).

2.8. *Waltheria operculata* Rose, Contr. U.S. Natl. Herb. 5: 183. 1899. Iconography: (Rondón 2008: 12). Figures 3O; 6K-O

Subshrubs prostate c. 50 cm tall; branches cylindrical, not flexuose, hirsute, trichomes simple. Stipules 7–11×3–5 mm, lanceolate, trichomes equal to branches. Leaves alternate-spirallate; petiole 0.5–1.5 cm long, pilose; leaf blades 1.8–5.2×0.7–2 cm, elliptic to lanceolate, green, discolorous, membranaceous, base cuneate, apex atenuate, margin serrate, both surfaces pubescent, trichomes simple. Inflorescence cymose in glomerule scorpioid, terminal; pedicels 1–2 mm long; bracteoles 2–3, 5–6 mm long, elliptic, green not canescent, with trichomes simple; calyx 5 mm long, campanulate, green with apex brownish, lobes with apex acuminate, externally sericeous, with trichomes simple, internally with trichomes only at the apex; petals flat, c. 7×2 mm, spatulate, yellow, glabrous; staminal tube c. 2 mm long, free portion of stamens c. 0.2 mm long in longistylous flowers, anthers dithecate, yellow; ovary c. 1×0.5 mm, obovoid, glabrous with operculum sericeous, 1 locule, 1 ovules per locule; styles 0.8–1 mm long in longistylous flowers, brevistylous flowers not observed, stigmas c. 2 mm long, ciliated. Capsule c. 3×1–1.5 mm, obovoid, dehiscence apical opercular, trichomes simple at the operculum, aculeus absent; seeds c. 2×1–1.5 mm, obovoid, dark brownish, verrucose, glabrous.

Specimens examined: BRAZIL, BAHIA: Paulo Afonso, povoado Arrastapé, 09º33′07.1″S 38º14′53.2″W 269m, 06.V.2014, fl.; fr., J.B. Lima et al. 315 (HUNEB); Entre os povoados Barrinha e Santo Antônio, 09º36′40″S 38º20′16″W 370m, 06.V.2014, fl.; fr., J.B. Lima et al. 328 (HUNEB); Estação Ecológica Raso da Catarina, próximo a base nova (3), 09º34′51.5″S 38º29′27.8″W 622m, 22.VII.2014, fl.; fr., J.B. Lima et al. 447 (HUNEB); Macururé, saída da cidade em direção a Chorrochó, 09º09′02″S 38º03′31″W 361m, 02.VI.2014, fl.; fr., J.B. Lima et al. 393 (HUNEB); Rodelas, Lote de Natan, perímetro irrigado 4.5, 08º51′16.7″S 38º44′49″W 330m, 03.VI.2014, fl.; fr., J.B. Lima et al. 405 (HUNEB).

The species is distributed in Bolivia, Colombia, Honduras, Mexico, Paraguay, Venezuela and Brazil (Rondón 2008). In Brazil was recorded in the Northeast Region (Bahia, Paraíba, Pernambuco, Rio Grande do Norte), Central-West (Goiás, Mato Grosso) and Southeast (Minas Gerais, Rio de Janeiro), where it occurs in Caatinga, Cerrado, Atlantic Forest and Swamp (Esteves 2015b). In the RCE, the species was collected in anthropized areas.

Waltheria operculata is recognized in the RCE by its prostrate subshrub habit; an indumentum consisting of solely simple trichomes; and fruits with opercular dehiscence. It flowers and fruits throughout the year.

2.9. *Waltheria rotundifolia* Schrank, Syll. Pl. Nov. 2: 65. 1828. Figures 3P; 6P-T

Subshrubs 50-70 cm tall; branches cylindrical, not flexuose, tomentose, canescent, trichomes stellate sessile. Stipules 5–7 mm long, linear-lanceolate, trichomes equal to branches. Leaves alternate-spirallate; petiole 0.5–1 cm long, tomentose; leaf blades 1.5–3.2×1.5–3 cm, orbicular, green canescent, concolorous, chartaceous, base obtuse to truncate, apex rounded, margin dentate to serrate, both surfaces velutinous, with trichomes stellate more dense on abaxial surface. Inflorescence cymose in glomerule, axillary and terminal; pedicels 1–2 mm long; bracteoles 2–3, 4–6 mm long, linear-lanceolate, green, with trichomes simple and stellate; calyx 4 mm long, campanulate, green with apex brownish, lobes with apex acuminate, externally sericeous, with trichomes simple, internally with trichomes only at the apex; petals flat, c. 5×2 mm, spatulate, yellow, trichomes simple internally; staminal tube c. 3 mm long in brevistylous flowers, c. 2 mm long in longistylous flowers, free portion of stamens c. 0.2 mm long, anthers dithecate, yellow; ovary c. 1×0.5 mm, ovoid to elipsoid, sericeous, 1 locule, 1 ovule per locule; styles c. 1.5 mm long in brevistylous flowers, c. 5 mm long in longistylous flowers, geniculated, trichomes simple sparse, stigmas ciliated. Capsule c. 5×4 mm, ovoid to ellipsoid, indehiscent, trichomes simple, aculeus absent; seeds 2×1 mm, ellipsoid, brownish, glabrous.

Specimens examined: BRAZIL, BAHIA: Paulo Afonso, Estação Ecológica Raso da Catarina, base velha 09º43′52.6″S 38º40′57.1″W 601m, 16.IV.2014, fl.; fr., J.B. Lima et al. 297, 300 (HUNEB); Povoado barrinha, 09º35′11.2″S 38º19′32.2″W 404m, 6.V.2014, fl.; fr., J.B. Lima et al. 326 (HUNEB); Jeremoabo, estrada do tamburi, em direção aos Quelés, 09º57′41.9″S 38º25′32.3″W 509m, 03.IX.2012, fl.; fr., J.B. Lima et al. 48 (HUNEB); Banzaê, povoado Salgado, estrada do pau branco, 10º35′55″S 38º41′56″W 306m, 15.I.2014, fl., J.B. Lima et al. 154 (HUNEB); Canudos, Parque estadual de Canudos, Vale da morte, 09º55′20.9″S 39º07′04.4″W 581m, 12.V.2014, fl.; fr., J.B. Lima et al. 358, 361 (HUNEB); Rodelas, Lote de Natan, perímetro irrigado 4.5, 08º51′16.7″S 38º44′49″W 330m, 03.VI.2014, fl.; fr., J.B. Lima et al. 403 (HUNEB); Macururé, estrada depois de Macururré em direção a Chorrochó, 08º54′59.1″S 39º01′04.5″W 328m, 02.VI.2014, fl.; fr., J.B. Lima et al. 397, 398 (HUNEB).

The species is recorded in arid regions of Texas, Mexico and Central America (Amorim et al. 2009). In Brazil it occurs only in the Northeast Region in the states of Bahia, Pernambuco, Piauí and Rio Grande do Norte, in environments of Caatinga and Cerrado (Esteves 2015b). It is common in anthropized areas and widely distributed in the study area.

In the RCE the species is characterized by having canescent branches and leaves, as well as orbicular, concolorous leaves. *Waltheria rotundifolia* is found with flowers and fruit throughout the year.

3. Grewioideae Hochr.

Subshrubs to trees. Leaves simple, entire to lobed, venation palmately. Flowers actinomorphic, bissexual, diclamid, usually solitary or in inflorescence terminal or axillary. Calyx with 5 sepals, free. Corolla with 5 petals, free. Stamens five to numerous, anthers dithecate, rimose, dorsifixed. Androgynophore or gonophore present or absent. Ovary super, with one to numerous ovules per locule, placentation axile. Fruit capsule or nucaceous.

Grewioideae comprises 25 genera and 700 species, the majority of which occur in tropical regions of the New and Old World (Bayer & Kubitzki 2003). It is represented in the study area by three genera and four species.

3.1. *Corchorus hirtus* L., Sp. Pl. 2(1): 747. 1762. Iconography: Shumann (1886: 26), Souza & Esteves (2002: 339), Tschá et al. (2002: 8). Figure 3Q

Subshrubs c. 50 cm tall; branches cylindrical, pubescent to glabrescent, trichomes simple sparse and a dense longitudinal line trichomes; stipules 4–5 mm long, linear, trichomes equal to branches. Leaves entires, alternate-spirallate; petiole 0.3–1.5 cm long, pubescent; leaf blades 1.7–5.8×0.9–2.3 cm, ovate to elliptic-lanceolate, green, discolorous, membranaceous, base obtuse to rounded, apex acute, margin serrate, both surfaces pilose, trichomes simple sparse. Inflorescence cymose, with 2 flowers, axillary or terminal; pedicels 9–10 mm long; sepals flat 8–10 mm long, oblong, apex acuminate, externally with trichomes simple, internally glabrous; petals c. 8×2.5–3 mm, obovate, yellow, glabrous; staminodes absents, androgynophore short, without glands, stamens 48, 6–7 mm long, free; ovary 2–3×*0.8*-1 mm, cylindric to elliptic, sericeous, 4 locules, numerous ovules per locule; styles 5 mm long, stigmas capitate. Capsule 1.8–3.9×0.2–0.3 cm, elongate-flattened, dehiscence longitudinal, hirsute, with trichomes simple; seeds c. 1.2×1 mm, tetragonal, blackened, without wings, glabrous.

Specimens examined: BRAZIL, BAHIA: Euclides da Cunha, Fazenda Binjé, do Sr. Alan, antes da barragem, 10º34′13.5″S 39º01′22.6″W 383m, 07.VIII.2014, fl.; fr., J.B. Lima et al. 514 (HUNEB); Jeremoabo, povoado Brejinho, ao lado do cemitério, 10º02′39.5″S 38º21′43.3″W 310m, 14.VIII.2014, fl.; fr., J.B. Lima et al. 518 (HUNEB); 25.XI.2014, fr., J.B. Lima et al. 571 (HUNEB).

The species is widely distributed in South America (Robyns 1964b), especially in Brazil, where it occurs in all regions, in different environments such as Amazon Rainforest, Caatinga, Cerrado, Atlantic Forest and Swamp. The species was cataloged for the majority of the states of the Northeast Region, except Rio Grande do Norte and Piauí (Bovini 2015). It was uncommon in the RCE, found in preserved and anthropized area.

Corchorus hirtus can be recognized by its indumentum of two branches composed of sparse simple trichomes, being denser where it forms a longitudinal line; alongate-compressed fruits; and by tetragonal seeds. It was collected with flowers and fruits in June to November. According to Sampaio et al. (2005), it has apicultural and fiber production potential.

3.2. *Luehea candicans* Mart., Nov. Gen. Sp. Pl. 1(4): 102. 1826. Iconography: Souza & Esteves (2002: 339). Figure 4K-M

Tree c. 5 m tall; branches cylindrical, young pubescent, trichomes stellate; stipules 0.4–0.8 cm ovate-acuminate, pubescent. Leaves entire, alternate-spirallate; petioles 0.3–0.4 cm long, pubescent, trichomes equal to branches; leaf blades 3.4–7×2–3.6 cm, semi-coriaceous, ovate to elliptic-lanceolate, green, discolorous, chartaceous to semi-coriaceous, apex acute to acuminate, base obtuse to subchordate, margin irregulary serrate, surface adaxial rough, glabrescent with trichomes stellate sparse, surface adaxial velutinous with trichomes stellate. Solitary flower, terminal; flower passed, not examined. Capsule 1.5–2.8×0.7–1.6 cm, obovoid to ellipsoid, loculicidal, green and tomentose when young, glabrescent and blackened when mature, trichomes stellate; seeds 0.8–1.1×0.3–0.5 cm, elliptic, winged at the apex, wing 0.5–0.8 cm, glabrous.

Specimens examined: BRAZIL, BAHIA: Euclides da Cunha, Fazenda Brinjé, do Sr. Alan, 10º34′17.8″S 39º01′08.7″W 376m, 07.VIII.2014, fr., J.B. Lima et al. 509 (HUNEB).

The species is distributed in Paraguay, Bolivia, Argentina and Brazil, where it is widely distributed in all states of the Central-West, Southeast and South regions in Cerrado and Atlantic Forest (Souza & Esteves 2002, Esteves 2015c). It is rare in the RCE, and was collected only once. This is the first record of the species for the state of Bahia.

Luehea candicans is recognized in the study area by its tree habit; simple leaves; and solitary flower. It was collected in the RCE with passed flowers and fruits in August. The species has ornamental and apicultural potential and its wood can be used in furniture manufacturing (Souza & Esteves 2002, Sampaio et al. 2005).

3.3. *Luehea paniculata* Mart., Nov. Gen. Sp. Pl. 1(4): 100. 1826. Iconography: Tschá et al. (2002: 11). Figure 5A-C
Popular name: açoita-cavalo.

Tree c. 8 m tall; branches cylindrical, young pubescent to tomentose, trichomes stellate, ferrugineous; stipules 2–3 mm long, linear, deciduous. Leaves entire, alternate-spirallate; petioles 0.7–1.3 cm long, trichomes equal to branches; leaf blades 6.5–12.8×3.2–8.3 cm, ovate-oblong, green, discolorous, coriaceous, base obtuse to subchordate, apex obtuse to acute, margin serrate, surface adaxial pubescent with trichomes stellate ferrugineous, surface abaxial lanuginose canescent and trichomes stellate ferrugineous sparse. Inflorescence paniculate, terminal and axillary; flowers not observed. Capsule 1.7–2.2×0.9–1.5 cm, oboval, loculocide, pubescent; seeds 8–9×3.8-4 mm, elliptic, apex winged, wing c. 6 mm long.

Specimens examined: BRAZIL, BAHIA: Cícero Dantas, estrada do Sapé, 10º19′32.5″S 38º35′26.2″W 622m, 05.VIII.2014, bt.; fr., J.B. Lima et al. 492 (HUNEB).

The species is distributed in Peru, Bolivia, Paraguay, Brazil, Argentina and Uruguay (Milward-de-Azevedo & Valente 2005).

In Brazil it has been recorded in all regions and in various environments such as the Amazon Rainforest, Caatinga, Cerrado, Atlantic Forest and the Pantanal. In the Northeast Region the species does not occur in the states of Rio Grande do Norte and Sergipe (Esteves 2015c). It is rare in the RCE, and was collected only once.

Luehea paniculata is recognized in the area by its tree habit; simple leaves canescent on the abaxial surface; and paniculiform inflorescences. It was collected in the study area with buds and fruits only in August. It has wood, medicinal and apicultural potential (Guimarães et al. 1993, Milward-de-Azevedo & Valente 2005, Sampaio et al. 2005).

3.4. *Triumfetta semitriloba* Jacq., Enum. Syst. Pl. 22. 1760. Iconography: Lay (1950: 374), Souza & Esteves (2002: 339), Tschá et al. (2002: 15), Alves et al. (2011: 15). Figure 3R
Popular name: carrapicho.

Subshrubs 1.3-1.5 m tall; branches cylindrical, pubescent, trichomes stellate; stipules 4–6 mm long, linear, trichomes equal to branches. Leaves entire to semi-trilobate, alternate-spirallate; petiole 2–3 cm long, tomentose; leaf blades 4–9 × 2.5–7.5 cm, largely ovate to elliptic, green, discolorous, membranaceous, base truncate to subchordate, apex acute-acuminate, margin irregulary serrate, both surfaces pubescent, with trichomes stellate. Inflorescence cymose, cymule with 3 to 5 flowers, axillary or terminal; pedicels 2–4 mm long; sepals cucullate 5–8 mm long, oblong, ellipsoid, with apicule at the extremities, externally with trichomes stellate, internally glabrous; petals 4.5–6 × 1–2 mm, elliptic-spatulate, yellow, ciliated; staminodes absents, gonophore 2–3 mm long with glands elliptic, stamens 12–15, 3.5–5 mm long, free; ovary 1–2 × c.1 mm, globose, pubescent, locules 3–4, 2 ovules per locule; styles 4–5.5 mm long, stigmas acute. Nucaceous c. 1 × 1 cm, including the apicule, globose, indehiscent, glabrescent to pubescent, spine uncinate with trichomes simple; seeds c. 0.2 × 0.1 mm, ellipsoid, beige to brown, without wings, glabrous.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, baixa grande depois dos Quelés, roça de Mané de Chico, 09º58′31″S 38º27′01″W 564m, 03.IX.2012, fl.; fr., D.D. Vieira et al. 386 (HUNEB), J.B. Lima et al. 53 (HUNEB); Baixa dos Quelés, depois da porteira, próximo a casa de Antônio Rouxinho, 09º57′30.3″S 38º26′20″W 504m, 12.XI.2013, fl., J.V. Santos et al. 96 (HUNEB); Estrada saíndo dos Quelés, sentido ESEC, 09º56′45.7″S 38º27′30.1″W 607m, 29.VII.2009, fl., T.M. Silva et al. 131 (HUNEB); Povoado Brejinho, 10º02′32″S 38º21′44.2″W 307m, 31.VII.2014, fl.; fr., J.B. Lima et al. 459 (HUNEB); Estrada depois da baixa da forra, indo para Quelés, 10º02′22.7″S 38º21′45.5″W 315m, 31.VII.2014, fl.; fr., J.B. Lima et al. 465 (HUNEB); Baixa do tamburi, 09º57′46″S 38º26′12″W 478m, 14.VIII.2014, fl.; fr., J.B. Lima et al. 520 (HUNEB); Cícero Dantas, boqueirão, em frente a casa de Jorge, 10º33′21.1″S 38º24′29″W 406m, 04.VIII.2014, fl.; fr., J.B. Lima et al. 477 (HUNEB); estrada do Sapé, 10º19′32.5″S 38º35′26.2″W 622m, 05.VIII.2014, fl.; fr., J.B. Lima et al. 493 (HUNEB).

It has a Pantropical distribution (Barroso 1978). It occurs throughout Brazil, with the exception of the states of Acre, Rondônia, Roraima, Amapá and Tocantins, in the Amazon Rainforest, Caatinga, Cerrado and Atlantic Forest (Esteves 2015d). Well collected in the RCE, the species is known only in the EPASB (Jeremoabo) and the municipality of Cícero Dantas.

Triumfetta semitriloba is recognized in the study area by the presence of 12–15 stamens; apically ellipsoid sepals; androgynophore with elliptical glands; and glabrescent to pubescent fruits but with uncinate spines containing simple trichomes. It was found with flowers and fruit throughout the year. The species has apicultural potential (Sampaio et al. 2005).

4. Helicterioideae (Schott e Endl.) Meisn.

Shrubs. Leaves simple, entire, venation palmately. Flowers zygomorphic, bissexual, diclamid, solitary or in inflorescence terminal or axillary. Calyx gamosepalous with 5 lobes. Corolla with 5 petals, free. Androgynophore present. Stamens 10, free; staminode 5, anthers dithecate, rimose, dorsifixed. Ovary super, with numerous ovules per locule, placentation axile. Fruit capsule spirallate.

The subfamily includes six genera and 70 species distributed in the tropical regions of the New and Old World (Bayer & Kubitzki 2003). Two species of the subfamily are recorded in the ecoregion.

4.1. *Helicteres eichleri* K. Shum., Fl. Bras. (Martius) 12(3): 16. 1886. Iconography: Cristóbal (2001: 103). Figures 3S; 5D-G

Shrubs 1.8-2 m tall; branches cylindrical, tomentose, trichomes stellate, more dense in the extremities; stipules 1–1.5 cm long, linear, trichomes equal to branches. Leaves alternate-spirallate; petiole 1–2 cm long, tomentose; leaf blades 3–8 × 2–5 cm, ovate to elliptic, green, discolorous, chartaceous, base rounded to subchordate, apex acute, margin serrated, both surfaces pubescent, with trichomes stellate, more dense on the abaxial surface. Inflorescence cymose, 2–flowers, axillary or oppositifolious; 2 profiles per flower, c. 1.3 cm long, linear, tomentose; pedicels 0.4–0.6 cm long, nectaries absent; calyx 1.8–2.5 cm long, tubulous, erect, red, lobes with apex acute-acuminate, externally pubescent, with trichomes stellate, internally with trichomes only at the apex; petals 4–5 × *c.* 5 mm, included, reduced to flabeliforms claw, alb, glabrous; androgynophore 3-4 cm long, erect, with trichomes stellate; staminodes 2 × 2.5 mm, elliptic; stamens 1–1.5 mm long; ovary c. 1.5 × 1 mm, ovoid, tomentose, 5 locules, c. 12 ovules per locule; styles 2.5–3 mm long, stigmas acute. Capsule 1.5–2.5 × 0.8–1 cm, cylindric, slightly ovoid, spirallate until a half, indehiscent, with trichomes stellate; seeds c. 2.5 × 2 mm, ellipsoid, dark brown, glabrous.

Specimens examined: BRAZIL, BAHIA: Jeremoabo, APA Serra Branca, estrada sentido Serra do Navio, 09º51′58.1″S 38º38′46.9″W 482m, 03.XI.2011, fl.; fr., J.B. Lima et al. 11 (HUNEB); estrada sentido Serra do Navio, depois do dedo de Deus, 09º52′43.4″S 38º39′14.5″W 463m, 11.II.2014, fl., J.B. Lima et al. 187 (HUNEB); 24.XI.2014, fl.; fr., J.B. Lima et al. 578 (HUNEB); estrada principal sentido Serra do Navio, 09º52′59″S 38º39′45″W 453m, 06.VI.2014, fl.; fr., J.B. Lima et al. 415 (HUNEB); Trilha do morrote, 09º52′16.7″S 38º38′43.9″W 474m, 30.VII.2014, fl.; fr., J.B. Lima et al. 456 (HUNEB); Trilha do araçá, 9,5 km de distância da base da APA, 09º52′49.1″S 38º38′13.5″W 535m, 08.V.2008, fl.; fr., M.V. Romão et al. 129 (HUNEB); Estrada sentido serra branca, 09º52′51.9″S 38º39′28.9″W 487m, 10.XII.2008, fl.; fr., M.V. Romão et al. 424 (HUNEB); Canudos, Parque estadual de Canudos, marco da degola, 09º54′54.6″S 39º07′05.7″W 379m, 10.V.2008, fl.; fr., M.V. Romão et al. 179 (HUNEB).

Restricted to the states of Alagoas, Bahia, Maranhão, Paraíba, Pernambuco and Sergipe, *Helicteres eichleri* is an endemic specie to Brazil and occurs in the Caatinga and Atlantic Forest (Cristóbal 2001, Esteves 2015e). In the RCE the species occurs only in areas of preserved Caatinga in the EPASB (Jeremoabo) and of State Park of Canudos (SPC).

It is distinguished from its congeners in the study area by having a straight calyx; included petals reduced to flabelliform claws; and a short androgynophore reaching up to 4 cm. It was found with flowers and fruits throughout the year.

4.2. ***Helicteres velutina*** K.Schum., Fl. Bras. (Martius) 12(3): 22. 1886. Iconography: Cristóbal (2001: 61), Cristóbal (2006: 109). Figure 3T

Shrubs 1.8-2.2 m tall; branches cylindrical, velutinous, trichomes stellate; stipules 5-7 mm long, linear, trichomes equal to branches. Leaves alternate-spirallate; petiole 1-1.5 cm long, tomentose; leaf blades 3.5–9×2–6.5 cm, ovate to elliptic, green, discolorous, chartaceous, base subchordate, apex acute, margin serrate, both surfaces velutinous, with trichomes stellate, more dense on abaxial surface. Inflorescence cymose, 2–flowers, axillary and terminal; 2 profiles per flower, 1-1.2 cm long, linear; pedicels 0.5–0.7 cm long, 1–3 nectaries; calyx 1.2–2.5 cm long, tubulous-campanulate, geniculated at the the base, red with base beige, lobes with apex acuminate, externally pubescent, with trichomes stellate, internally with trichomes only at the apex; petals 2–3.5×0.8–1.2 cm, unguiculate, orange to red, glabrous, claw 12–17×1–2 mm, wings fringes; androgynophore 6–8 cm long, curved, glabrous; staminodes c. 2.5 mm, elliptic; stamens 2–3 mm long; ovary 1.5–2 mm, ovoid, tomentose, 5 locules, c. 16 ovules per locule; styles 2.5–4 mm long, stigmas acute. Capsule 1.5–3×1–1.5 cm, cylindrical, spiraled until a half, dehiscencia apical, with trichomes stellate; seeds 2.1–2.8×1.5–2 mm, tetragonal, beige with brown macules, glabrous.

Specimens examined: BRAZIL, BAHIA: Paulo Afonso, Estação Ecológica Raso da Catarina, trilha do tansecto, 09º39′50.7″S 38º28′01.4″W, 17.VIII.2010, fl.; fr., C.L.S.B. Correia et al. 175 (HUNEB); Trilha próximo a casa sede do ICMBio, 09º39′84.2″S 38º28′00.6″W 592m, 4.IV.2011, fl., C.L.S.B. Correia et al. 434 (HUNEB); Trilha sentido casa 02, 09º50′11.4″S 38º29′47.3″W 670m, 4.V.2011, fl., C.L.S.B. Correia et al. 442 (HUNEB); Trilha sentido pedra da janela, 09º40′00.8″S 38º27′59.5″W 575m, 25.VII.2011, fl.; fr., C.L.S.B. Correia et al. 502 (HUNEB); Trilha sentido mata da Pororoca, próximo a casa do Sr. Divá, 09º42′23.9″S 38º29′46.1″W 645m, 27.VII.2011, fl.; fr., C.L.S.B. Correia et al. 526 (HUNEB); Após a mata da Pororoca, 09º48′46.3″S 38º29′31″W 698m, 18.III.2014, fl.; fr., J.B. Lima et al. 194 (HUNEB); Estrada em direção a base velha, 09º51′38.7″S 38º29′29.3″W 635m, 18.III.2014, fl.; fr., J.B. Lima et al. 196 (HUNEB); Trilha sentido Pororoca, depois da casa do Sr. Divá, 09º45′12.5″S 38º29′29.2″W 655m, 15.IV.2014, fl.; fr., J.B. Lima et al. 274 (HUNEB); 24.XI.2014, fl.; fr., J.B. Lima et al. 570 (HUNEB); Base nova (3), 09º34′51.5″S 38º29′27.8″W 622m, 03.IX.2014, fl.; fr., J.B. Lima et al. 536 (HUNEB); ESEC, mata da Pororoca, 09º48′28.1″S 38º29′30.9″W 699m, 19.V.2010, fl.; fr., M.V. Romão et al. 606 (HUNEB); 09º48′39.6″S 38º29′31″W 707m, 24.IX.2013, fl.; fr., J.B. Lima et al. 105 (HUNEB); 07.V.2014, fl.; fr., J.B. Lima et al. 337 (HUNEB); 09.VI.2014, fl.; fr., J.B. Lima et al. 422 (HUNEB); 21.VII.2014, fl.; fr., J.B. Lima et al. 438 (HUNEB); Cícero Dantas, estrada do Sapé, 10º19′27″S 38º35′52.9″W 611m, 5.VIII.2014, fl.; fr., J.B. Lima et al. 489 (HUNEB); Canudo, Estação Biológica de Canudos, depois do riacho em direção ao saco 1, 09º57′05.7″S 39º00′07.9″W 413m, 27.III.2014, fl.; fr., J.B. Lima et al. 248 (HUNEB); Saindo do saco 1, em direção ao saco 2, depois do Jatobá, 09º57′06.3″S 38º59′58.4″W 403m, 14.V.2014, fl.; fr., J.B. Lima et al. 382 (HUNEB); Jeremoabo, APA Serra Branca, estrada que vai da ESEC em direção ao povoado Quelés, 09º53′01.8″S 38º32′39.5″W 650m, 22.IX.2010, fl.; fr., D.D. Vieira et al. 82 (HUNEB); Estrada principal de Quelés, em direção a divisa APA-ESEC, 09º57′53″S 38º26′30″W 500m, 17.VI.2011, fl.; fr., D.D. Vieira et al. 177 (HUNEB); Caminho da ESEC em direção a Quelés, 09º57′21.5″S 38º26′22.5″W, 502m, 09.IX.2009, fl.; fr., M.V. Romão et al. 546 (HUNEB); 09º57′28.9″S 38º26′18.6″W 502m, 09XII.2009, fl.; fr., M.V. Romão et al. 563 (HUNEB); Estrada do tamburi, próximo a baixa dos Quelés, 09º57′43″S 38º25′33.3″W 514m, 09.VII.2012, fl.; fr., J.B. Lima et al. 23 (HUNEB); Depois de Olho D'água dos negros, 10º01′00.7″S 38º22′30″W 438m, 5.VI.2014, fl.; fr., J.B. Lima et al. 411 (HUNEB).

Endemic to Brazil, *Helicteres velutina* occurs in the Northeast (Bahia, Ceará, Pernambuco) and Southeast (Minas Gerais) regions, in the areas of Caatinga, Cerrado and Atlantic Forest (Cristóbal 2001, Esteves 2015e). In the RCE, the species is widely distributed in areas of preserved Caatinga.

Helicteres velutina is recognized in the RCE by its velutinous branches, leaves and fruits; calyx geniculate at the base; and by a curved and long androgynophore attaining 8 cm in length. It possessed flowers and fruits throughout the year.

Supplementary material

The following online material is available for this article:

Appendix 1 - List of additional material examined.

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Author Contributions

Jéssica Batista Lima: Contribution to the acquisition of data; analysis and interpretation of data; work of writing and conception and design work.

Massimo Giuseppe Bovini: Contribution to the interpretation of data and critical review adding intellectual content.

Adilva de Souza Conceição: Contribution to the acquisition of data; analysis and interpretation of data; work of writing; critical review adding intellectual content and conception and design work.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Article

Diversity of springtails (Collembola) in agricultural and forest systems in Southern Santa Catarina

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Abstract: The aim of this study was to evaluate the influence of soil use on the morphological diversity of springtails and to verify the relationship of these organisms with soil physical, chemical, and microbiological properties. Samples were collected in the Southern region of Santa Catarina, involving three municipalities: Orleans, Lauro Müller, and Siderópolis, in the land use systems (LUS) of native forest (NF), *Eucalyptus* plantation (EP), pasture (PA), integrated crop-livestock (ICL), and no-tillage (NT). Soil samples to determine edaphic properties and pitfall traps were collected in winter and summer, in the same areas. The collected springtails were counted and morphotyped and the data were analyzed through abundance, Shannon-Wiener diversity (H') and Margalef index, Simpson dominance index (D), Pielou evenness index (J), morphotype richness, and Principal Components Analysis (PCA). Springtails morphotypes were influenced by the management conditions of each system, especially the impact of LUS on these organisms depends on the intensity of the forest/agricultural practices used, including crop rotation and soil preparation.

Keywords: *Collembola morphotypes, bioindicators, soil quality, edaphic mesofauna.*

Diversidade de colêmbolos (Collembola) em sistemas agrícolas e florestais no Sul de Santa Catarina

Resumo: O objetivo deste estudo foi avaliar a influência do uso do solo na diversidade morfológica de colêmbolos e verificar a relação destes organismos com os atributos físicos, químicos e microbiológicos do solo. Foram coletadas amostras na região Sul de Santa Catarina, envolvendo três municípios: Orleans, Lauro Müller e Siderópolis, nos sistemas de uso do solo (SUS) de floresta nativa (FN), reflorestamento de eucalipto (RE), pastagem perene (PA), integração lavoura-pecuária (ILP) e plantio direto (PD). As coletas de solo para determinação dos atributos edáficos e a instalação de armadilhas de queda, foram realizadas no inverno e verão, nos mesmos pontos. Os colêmbolos coletados foram contados e morfotipados e os dados foram analisados por meio da abundância, diversidade de Shannon-Wiener (H') e Margalef, índice de dominância de Simpson (D), uniformidade de Pielou (J), riqueza de morfotipos e Análise de Componentes Principais (ACP). Os morfotipos de Collembola foram influenciados pelas condições de manejo de cada sistema, sobretudo o impacto dos SUS nesses organismos depende da intensidade das práticas florestais/agrícolas utilizadas, incluindo rotações culturais e preparo do solo.

Palavras-chave: *Morfotipos de Collembola, bioindicadores, qualidade do solo, mesofauna edáfica.*

Introduction

Springtails are small arthropods of the edaphic mesofauna, belonging to the Collembola Class. They participate in the control of fungi biomass in the soil, also acting as its dispersers, besides serving as food for several other animals and mainly act indirectly in the decomposition of organic matter (Berude et al. 2015). The abundance and diversity of springtails in agricultural and forest systems depend on different biotic and abiotic factors, but in general, the factors may be related to climate (time of year), pH, release of certain ions and humidity, besides the appearance of substances that make up pesticides and/or metals (Cassagne et al. 2003, 2004, Oliveira Filho & Baretta 2016).

In addition, they show a vertical distribution along the layers of the soil, being able to be found three life forms (eco-morphological groups), based on their degree of adaptation to the soil, separated according to morphological characteristics (traits), being: epigeous, those more adapted to the plant litter; hemiedaphic are the intermediates that live between the 5 cm of the soil surface; and the edaphic ones, more adapted to the soil, that lives below 5 cm of the surface (Oliveira Filho & Baretta 2016). This classification can be adopted when a rapid assessment on biodiversity is required since it requires less identification time (practicality), less specific knowledge in taxonomy and materials, when compared to identification at family, gender and species levels (Reis et al. 2016).

In this sense, because they present different life strategies in the vertical stratification of the soil and because of their sensitivity to environmental changes, the springtails are being used as bioindicators of soil quality (Baretta et al. 2014, Rieff et al. 2016), since they are sensitive to changes in soil and in vegetal cover, caused by anthropic activities or by natural causes (Oliveira Filho & Baretta 2016). In addition, they show sensitivity to temperature changes (Rieff et al. 2014), precipitation and humidity (Oliveira Filho & Baretta 2016) and pesticide application (Lima & Silva et al. 2017).

Even with such importance, there is still a lack of studies in Brazil that deal with the biological quality of the soil. In Santa Catarina, studies with this theme are even more incipient, especially in the case of springtails as bioindicators (Oliveira Filho et al. 2016, Santos et al. 2018). Studies with this type of approach allow a better understanding of how intensive management practices may be harmful to biological diversity and, consequently, how they impact several ecosystem processes, such as nutrient cycling and organic matter decomposition. Hence, less intensive management practices can ensure equilibrium in the soil and in the environment as a whole, such as that found in more conservative agricultural systems and native forests, for example.

Thus, to study the diversity of springtails present in different land use systems allows to evaluate which system conserves better the biological quality of the soil. Therefore, the objective of this study was to evaluate the effect of soil use intensity on the morphological diversity of springtails, as well as their relationship with soil chemical, physical and microbiological properties, in the southern region of Santa Catarina, using the technique of morphotyping as an alternative to traditional taxonomy.

Material and Methods

1. *Study area*

The study was carried out in the municipalities of Orleans, Lauro Müller, and Siderópolis, in the southern region of the state of Santa Catarina (SC) (Table 1). The climate of the southern region is characterized by Köppen as mesothermal moist, with hot summer (Cfa). The soils found were classified as *Argissolo Vermelho-Amarelo* (Typic Hapludult), derived from siltstone, formation in Rio Bonito, Lauro Müller, and Siderópolis; *Argissolo Vermelho-Amarelo* (Typic Hapludult), derived from granite, intrusive suite, in Orleans.

The land use systems (LUS) studied include: native forest (NF), *Eucalyptus* plantation (EP), pasture (PA), integrated crop-livestock (ICL), and no-tillage (NT), with the purpose of establishing a gradient of anthropogenic intervention, considering less interference in NF and greater interference in NT. The selection of the areas in each of the three municipalities sought similar environmental conditions that allowed the comparison between the systems, such as similar management history, geographic characteristics and even soil type. Information on the characteristics and history of the areas are shown in Table 1.

2. *Experimental design and sampling*

Samples were collected at two distinct seasons, winter (July 2011) and summer (January 2011). Sampling in each treatment (LUS) occurred in a sample grid of 3×3 points, with spacing between each point of 30 m (to avoid autocorrelation) and 20 m of border, totaling 1 ha for each area, same scheme used by Oliveira Filho et al. (2016) and Santos et al. (2018). This sampling would result in 270 samples in total, as it was considered three municipalities, in which five LUS were analyzed, and in each LUS nine sample points, in two periods (winter and summer). However, for the analyzes of this study, only the first five sample points cataloged (totaling 150 samples) were considered, because the number of springtails per sample was very high and, therefore, it was considered that five samples would already be representative of the community.

For the evaluation of soil chemical and microbiological properties, fifteen subsamples were collected around approximately 0.10 to 0.20 m from each of the sampling grid points in the 0.00-0.20 m layer to form a representative composite sample. For the soil physical properties, samples were collected with structures preserved in steel cylinders, 5 cm in diameter and 5 cm in height (undeformed).

3. *Sampling and morphotyping of springtails*

The springtails were captured by pitfall traps containing a solution of approximately 200 mL of water with detergent (3:1 ratio), installed at each of the sample points and maintained in the field for 72 hours. Afterward, they were collected, sorted, separated and fixed in absolute alcohol (99.5%) for preservation. Specimens of this survey are housed at the Collection of the Universidade do Estado de Santa Catarina.

Then, the springtails were counted and separated in different morphotypes, using a stereoscopic microscope with an increase of up to 50 times. The separation of springtails in morphotypes

Table 1. Characteristics of land use systems, native forest (NF), *Eucalyptus* plantation (EP), pasture (PA), integrated crop-livestock (ICL) and no-tillage (NT) in the municipalities of Orleans, Lauro Müller and Siderópolis, in the southern region of Santa Catarina.

Municipalities	System	Size (ha)	UTM Coordinate (zone J22)	Time of use of the area	Management history
Orleans	NF	-	W 49°15'37.501" S 28°22'37.892"	-	Atlantic Forest, Dense Ombrophilous Forest formation.
	EP	4	W 49°14"53.269" S 28°22"37.892"	12 years	*Eucalyptus* sp., previously a native forest.
	PA	1.5	W 49°15'34.255" S 28°22'45.453"	+ 50 years	Native pasture, with the presence of broad-leaf grasses, entry of 15 heads of cattle.
	ICL	2	W 49°15'7.924" S 28°22'42.777"	2 years	Conventional plantation, with the presence of poultry and cattle litter in an average stocking of 10 heads ha^{-1}.
	NT	4	W 49°15'36.806" S 28°22'42.777"	3 years	Limestone was used in the area (7 Mg ha^{-1}).
Lauro Müller	NF	-	W 49°26'8.169" S 28°21'16.906"	-	Atlantic Forest, Dense Ombrophilous Forest formation.
	EP	3	W 49°26'28.526" S 28°21'8.065"	20 years	*Eucalyptus* sp., it was pasture before reforestation.
	PA	2	W 49°26'12.281" S 28°21'12.525"	+ 20 years	It was always native pasture, used three years before the study of chicken manure, with the entry of 8 to 10 heads of cattle.
	ICL	1	W 49°26'9.674" S 28°21'24.461"	3 years	With the rotation of corn in the summer and ryegrass in the winter, cattle in the average stocking of 10 heads ha$^{-1.}$
	NT	2	W 49°6'10.869" S 28°21'33.104"	3 years	Corn in summer and oats in winter, 250 kg ha^{-1} of NPK was used.
Siderópolis	NF	11	W 49°30'27.18" S 28°35'0.471	Always	Atlantic Forest, Dense Ombrophilous Forest formation.
	EP	6	W 49°29'4.540" S 28°35'11.284"	9 years	*Eucalyptus* sp. was previously planted with corn, with the entry of cattle and thinning in July 2012.
	PA	9	W 49°29'56.445" S 28°34'56.380"	30 years	Mixed pasture with 20 heads of cattle.
	ICL	11	W 49°30'15.6" S 28°35'03.7"	6 years	Conventional plantation, cattle with an average stocking of 10 heads ha^{-1}.
	NT	4	W 49°29'8.103" S 28°35'9.707"	3 years	Planting of corn and potato, liming, application of NPK and urea.

"-": absence of information.

followed the methodology used in the studies of Oliveira Filho et al. (2016) and Santos et al. (2018). This methodology is based on the springtails adaptation to the soil, evaluated according to the EMI (Eco-morphological index), which is based on the observation of five morphological traits for each springtail: presence or absence of ocelli, bristles and/or scales, pigmentation, antenna length, and furcula (Reis et al. 2016). To each of these traits was assigned a partial EMI value, and the sum of these values (total EMI) indicates a greater or lesser adaptation of the springtail to the soil. The higher the value of the total EMI, the greater its adaptation to the soil and the lower the dispersion power of the organism, and vice versa. This index can vary between 0 and 20 (Oliveira Filho et al. 2016, Santos et al. 2018).

Thus, for each different combination of the five traits a morphotype (morphological form) was assigned, allowing them to be separated into three eco-morphological groups, being: edaphic (with life in soil), which encompasses morphotypes with total EMI value ranging from 14 to 20; hemiedaphic, with values between 8 to 12, and epigeous (litter inhabitants), those with values between 0 to 6. Each combination of morphological characteristics that correspond to a given morphotype can be found in Santos et al. (2018).

It is worth mentioning that the use of morphotypes to study the community of Collembola make it possible to understand both the functional role of organisms and the influence of habitat alterations, and is able to provide reliable data that resemble species richness (Reis et al. 2016). The nomenclature of the morphotypes, used in the present study, refers to the eco-morphological group to which they belong, so Ed refers to the edaphic, H to the hemiedaphic, and Ep to the epigeous.

4. *Chemical, physical and microbiological analyzes of the soil*

The determination of the chemical properties occurred according to the methodologies of Tedesco et al. (1995), being: pH in water, Ca^{2+}, Mg^{2+}, Al^{3+}, potential acidity (H+Al), Mg/K, organic matter (OM), and C/N ratio. The soil physical properties such as total porosity (TP), microporosity (Micro), macroporosity (Macro), and biopores (Bio) were determined according to Claessen (1997) methodologies. Soil volumetric moisture was determined in the laboratory with samples dried in an oven at 105 °C for 24 hours. For the properties related to soil carbon dynamics, the carbon of the microbial biomass (MBC) was determined by the fumigation-extraction method (Vance et al. 1987) and the microbial activity determined by microbial basal respiration (MBR) (Alef & Nannipieri 1995). With the results of MBR and MBC, the metabolic quotient ($q\mathrm{CO}_2$) was calculated (Tótola & Chaer 2002). Total organic carbon (TOC) was determined by dry combustion by the CNHS Vario EL Cube Elemental Analyzer. Fresh soil samples were used to quantify microbiological properties and the results were expressed on dry soil.

5. *Data analysis*

The analyzes were performed at LUS level, using the values of three municipalities (true replicates of LUS) and five samples per municipality (n=3×5=15). The Collembola morphotypes were analyzed by abundance, Shannon-Wiener (H'), Margalef diversity index, Simpson dominance index (D), Pielou evenness index (J), and morphotype richness for each LUS, using the PAST 3.0 Software.

In order to compare the results among the LUSs in each age, we used variance analysis (ANOVA) of the main effects using the Newman-Keuls post-hoc test ($p<0.05$), and for the variables that did not meet the normality assumptions and homogeneity, even after the data transformation, the Kruskal-Wallis non-parametric test was used, both tests using the program STATISTICA version 7.

In addition, the abundance of morphotypes was subjected to Detrended Correspondence Analysis (DCA), to obtain the value of the gradient length, which presented a result lower than three (≤ 3), meaning that the data showed a linear response, recommending the user Principal Component Analysis (PCA).

The abundance of morphotypes was used as response variable (effect) and the soil physical, chemical, and microbiological properties were used as explanatory environmental variables in the PCAs. The collinear explanatory variables were verified by the variance inflation factor and by forward selection interventions, performing continuous Redundancy Analysis (RDA) based on Monte-Carlo test permutations for each type of variable, the explanatory variables that presented collinearity were withdrawn and those that best explained the variation of the data ($p\leq 0.05$) were selected. Thus, it was possible to choose a minimum set of significant physical, chemical and microbiological variables, which best explain the variation of Collembola morphotypes in each collection season. Finally, only the significant RDA variables were later used in the PCAs as explanatory environmental variables, which clarified the changes observed for the morphotypes. For the accomplishment of the multivariate analysis (DCA, RDA, and PCA), the statistical software CANOCO version 4.5 was used.

Results

1. *Abundance, richness, and diversity of morphotypes*

Eighteen Collembola morphotypes were found in the studied LUS, regardless the collection season, of which two belong to the edaphic (Ed) eco-morphological group, 10 to the hemiedaphic (H), and six to the epigeous (Ep). In the summer, 22,248 springtails were distributed in 18 morphotypes and 24,376 springtails in the winter, distributed in 12 morphotypes, totaling 46,624 springtails. The morphological group that presented the greatest representativity was the hemiedaphic with 46,002 individuals (98.67% of the total abundance) followed by the epigeous with 448 organisms (0.96%) and with the smaller number of edaphic representatives, with 174 springtails (0.37%). The most representative morphotypes were: H48 (48.47%), H32 (37.44%), and H50 (9.90%). While the least expressive, considering the abundance equal to and less than 15 individuals, were the morphotypes H35, H57, and Ep24 (0.002%).

The total abundance of springtails in the winter showed a difference ($p<0.05$) between the LUS (Figure 1A), in which the ICL presented the greatest abundance of springtails, without, however, differing from NT and PA. Meanwhile, NF presented the lowest abundance of springtails, not differing from EP, and ER being equal to PA. In the summer, NT presented the greatest abundance of springtails, differing from the other LUS. For the richness of morphotypes found in winter (Figure 1B), the ICL system presented the highest richness value, differing from of the other LUS.

For the Shannon diversity index (H'), in winter, it varied only between EP and ICL, where EP presented the lowest value and ICL the largest. For the Pielou index (J), the NF showed the highest value and did not differ only from the ER, while the other LUSs studied were similar to each other. The Margalef diversity was higher in NF, but it did not differ from PA, while ICL and NT were similar and the lowest value was in EP (Table 2).

In summer, for the H' index, the NT system was different from all studied LUSs, presenting the lowest value of diversity, while the other LUSs did not present significant differences. For the Margalef diversity, the NT had the lowest value, while the highest value was observed in the NF (Table 2).

2. *Analysis of community composition*

The PCAs for the abundance of springtails morphotypes, both in winter (Figure 2A) and in summer (Figure 2B), showed differences between LUS. In winter (Figure 2A), the total variability of springtails morphotype abundance was explained in 46.3% by principal component 1 (PC1) and 14.9% by PC2, totaling 61.3%. It is observed through the PCA a clear separation of LUS referring to the intensity of soil use, where NF was separated from the other LUS, the EP and PA were close and far from NT and ICL, which were related to each other.

The EP and PA systems seem close, but the EP was not related to any specific morphotype, whereas the PA was related to a hemiedaphic morphotype (H46). On the other hand, the NT and ICL systems, which were close and similar, were the LUS that related to most of the morphotypes (Ed6, Ed15, H48, H32, H50, H4, Ep9, Ep5, and Ep17), distributed in all the eco-morphological groups. Native forest in winter was related to only two epigeous morphotypes (Ep24 and Ep21).

The environmental variables used in the PCA help to explain the distribution of morphotypes in each LUS, through the association that they showed after being projected *a posteriori* in the analysis. Thus, in winter, TP, $q\mathrm{CO}_2$, and moisture contribute to explain the abundance of morphotypes in the NF. While K and pH explain the morphotypes associated with NT and ICL. The OM variable was very close to the ordering center, not being associated with any LUS, but it was closer

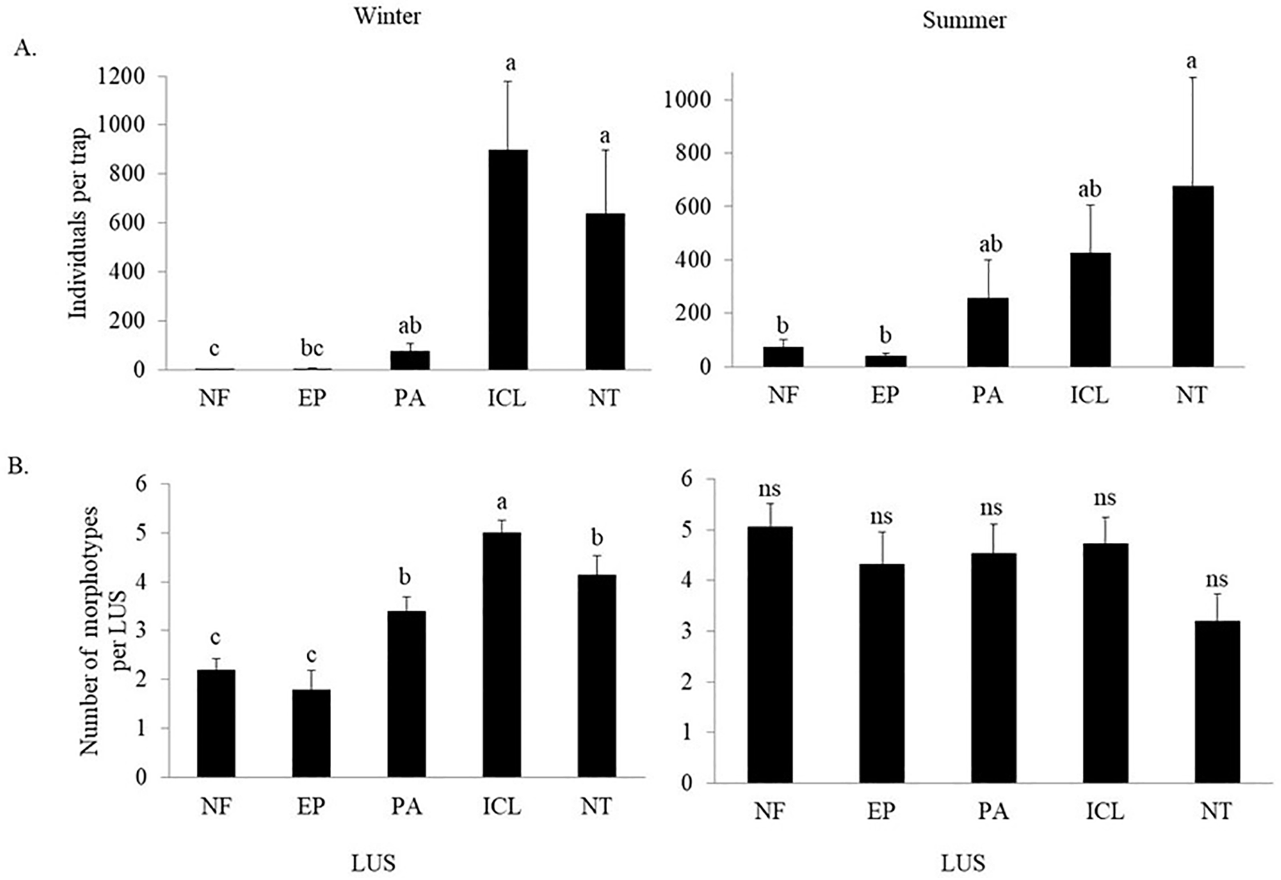

Figure 1. Springtails average abundance [individuals per trap] (A) and richness of morphotypes [number of morphotypes per LUS] (B), in the southern region of Santa Catarina, in native forest (NF), *Eucalyptus* plantation (EP), pasture (PA), integrated crop-livestock (ICL) and no-tillage (NT), in winter and summer. ns: not significant. The summer means followed by the same letter in the bars do not differ from each other by Newman-Keuls test ($p<0.05$; n=15). * Winter means values followed by the same letter in the bars do not differ from each other by the Kruskal-Wallis test of multiple comparisons ($p<0.05$, n=15).

Table 2. Values of Shannon (H') and Margalef diversity indexes, Pielou evenness index (J), Simpson dominance index (D) in native forest systems (NF), *Eucalyptus* plantation (EP), perennial pasture (PA), integrated crop-livestock (ICL), and no-tillage (NT), in winter and summer in the southern region of Santa Catarina.

LUS	NF	EP	PA	ICL	NT
			Winter		
Shannon diversity (H')	0.65ab	0.44b	0.73ab	0.85a	0.75ab
Pielou evenness (J)*	0.95a	0.73ab	0.69b	0.52b	0.60b
Margalef diversity	0.92a	0.48c	0.88ab	0.78b	0.70b
Simpson dominance (D)	0.58ns	0.55ns	0.57ns	0.52ns	0.57ns
			Summer		
Shannon diversity (H')	1.06a	0.97a	0.90a	0.82a	0.53b
Pielou evenness (J)*	0.63ns	0.60ns	0.59ns	0.48ns	0.44ns
Margalef diversity	1.18a	0.96ab	0.82ab	0.75bc	0.50c
Simpson dominance (D)	0.44ns	0.37ns	0.45ns	0.49ns	0.52ns

ns: not significant. The summer means followed by the same letter in the bars do not differ from each other by Newman-Keuls test ($p<0.05$; n=15). * Winter means values followed by the same letter in the bars do not differ from each other by the Kruskal-Wallis test of multiple comparisons ($p<0.05$, n=15).

to the Ep9 morphotype. For LUS, EP, and PA, they did not have any variables that contributed to the explanation of the springtails morphotypes abundance (Figure 2A).

In summer (Figure 2B), the total variability of the springtails morphotype abundance data was explained in 26.8% by PC1, and 17.5% by PC2, totaling 44.3%. Native forest and EP seem close, but EP was related to only one hemiedaphic morphotype (H30), whereas, NF showed a relation with six morphotypes (Ed6, Ed15, H25, H46, Ep21, and Ep24), distributed among all eco-morphological groups. Next, PA and NT seem to be close, but little related to the abundance

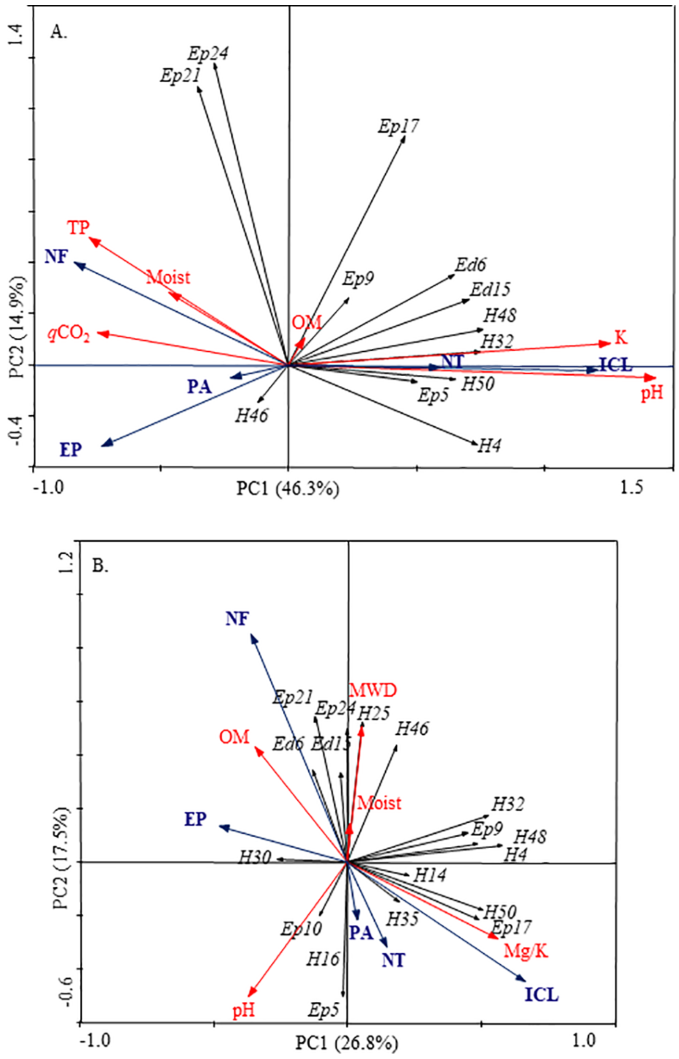

Figure 2. The relationship between the principal components 1 (PC1) and 2 (PC2) of the Principal Component Analysis (PCA), the Collembola morphotypes (black arrows) and their relation to the land use systems (blue arrows) and the environmental variables (red arrows) used as explanatory variables, in winter (A) and summer (B), in the southern region of Santa Catarina. NF: native forest; EP: *Eucalyptus* plantation; ICL: integrated crop-livestock; PA: pasture; NT: no-tillage; Ed: edaphic springtail; H: hemiedaphic springtail; Ep: epigeous springtail; K: potassium; pH: potential hydrogen; OM: organic matter; $q\text{CO}_2$: metabolic quotient; TP: total porosity; Moist: soil moisture; Mg/K: magnesium/potassium ratio; MWD: mean weight diameter of soil aggregates.

of springtails (H16, Ep10, and Ep5); while ICL, even with proximity to NT and PA, has a relation with more morphotypes, total of eight (H32, H48, H4, H14, H35, H50, Ep17, and Ep9) belonging to the group of hemiedaphic and epigeous (Figure 2B).

The properties OM, MWD, and moisture explained the occurrence of morphotypes in the NF in the summer. Meanwhile, the Mg/K ratio explains the morphotypes associated with ICL, and pH was the variable that best contributed to explain the morphotypes associated with PA and NT. *Eucalyptus* plantation had no variable explaining the abundance of springtails morphotypes (Figure 2B).

Discussion

1. *Abundance, richness, and diversity of morphotypes*

Normally, due to the quality of the environment, the diversity of plant species and the microclimate established, it is expected an increased abundance of organisms in the areas of NF. On the other hand, the greater abundance in NT and ICL may be related to the good management adopted in these systems, with the maintenance of cultural residues on the soil surface, improving the microclimate for edaphic fauna (Bartz et al. 2013). In addition to the maintenance of cultural residues, which can be observed in the history of NT and ICL (Table 1), there is also crop rotation between winter and summer, which favors more diversified habitat and with different food offerings.

Above all, some studies indicate that the application of exogenous substances, organic fertilizers, increases the activity of microorganisms (Zhang et al. 2014), which is a food source for many springtails and mites. From the history of the LUS (Table 1), it can be observed that the ICL system located in Orleans had poultry litter applied, which consequently provides a greater amount of organic matter, influencing the microbial biomass that serves as food for the springtails (Berude et al. 2015), favoring the development of its population.

Another determinant factor for the abundance of organisms in the LUS may be the presence of natural predators, which may have contributed to the fact that the NF did not present, in any of the stations, higher values of springtails abundance, possibly because they had a higher performance or more predators that in other LUS. In the study by Machado et al. (2015), when analyzing the community of edaphic organisms in forests with different stages of succession (initial stage, secondary in medium stage, and secondary in advanced stage), verified a higher number of Collembola (Entomobryomorpha) in sites with initial and medium stage of succession than in advanced stages, one of the possible explanations was that in these areas there was no expressive participation of predatory groups, which could control the populations of Collembola.

Low values of the abundance of springtails in *Eucalyptus* plantation, in two seasons, may be related to the plant material provided by this species, since the *Eucalyptus* plantations are biologically poor for providing low nutritional quality material, which consequently implies food resources of low quality in this system. In the study by Martins et al. (2013), when analyzing the effect of the essential oils present in the degradation of *E. globulus* leaves, using a reproduction and leakage test with springtails of *Folsomia candida* species, verified that the eucalyptus oils affected both the reproduction and the feeding preference of the springtails.

In the study by Santos et al. (2018), in the same LUSs in the eastern region of Santa Catarina, they found greater values of richness in the NF and ICL systems in winter, although the ICL did not differ from the NT and PA systems. For the authors, what influences the richness of morphotypes is the functional diversity and the least perturbation in areas of NF, associated to the diversity of the vegetation, providing several trophic and habitat resources for the springtails. These authors brought important points to be observed in the results found in the present study, in which the cultivation system as ICL presented positive results regarding the richness of species of springtails and what was expected was that higher values were found in the NF of according to the intensity of land use. Thus, we can highlight the advantages of a mixed production system, more sustainable than conventional systems, specializing in only one crop. This type of system has as advantages the synergism between the pastures and the annual crops used, which positively affects the physical, chemical and biological properties of the soil (Vilela et al. 2011). In a study by Tsiafouli et al. (2015) analyzing groups of earthworms, springtails, and mites in all regions of Europe, observed that the richness of these groups was negatively influenced by the increase in the intensity of soil use.

In addition, one of the main characteristics of this system is the entry and replenishment of soil organic matter (SOM), reducing its fluctuation, which normally occurs during the grazing period for grazing (SOM increases during grazing period and decreases in the period of grains), thus having a better equilibrium as regards the content of SOM (García-Préchac et al. 2004, Almeida et al. 2017). Finally, it favors the presence of organisms of the fauna of the soil, as the springtails, because there are refuges, different alimentary resources and a greater diversity of vegetal species, when compared to conventional crops, that use monoculture and solved of the ground.

The indices addressed in this study did not show the expected pattern of land use intensification (NF<EP<PA<ICL<NT). However, one of the factors that may raise the diversity of Collembola in a given environment, in the case of ICL in winter and NF in summer, is the richness of plant species. Sabais et al. (2011) found that the richness of plant species led to the greater diversity of Collembola species in temperate pastures.

In addition, higher values of H' (winter and summer) and Margalef (winter) in NF were also found by Santos et al. (2018). The authors commented that Margalef less than 2.0 indicates areas of low diversity and H' generally varies from 1.5 (low diversity) to 3.5 (high diversity), so, they pointed out that although the results found indicated low diversity, as in the present study, this indicates that this diversity is naturally low in NF and even higher than the other LUS. The factors that may be associated with this scenario are the lower temperature and humidity variations, together with the larger litter deposit in the NF, environment conducive to springtails.

It was found that having high abundance in the system does not necessarily reflect higher values of richness and diversity index. Higher values of springtail abundance, as found in NT in summer (Figure 1A) and higher value in index D (Table 2) may mean higher dominance of one or a few species, which may reflect less diversity and consequently lower resilience to ecosystem services (Baretta et al. 2011).

In the case of ICL, which in winter showed higher abundance (Figure 1A) and the lower value of D index (Table 2), not following the same pattern occurred in the NT above, may be related to the management adopted in the ICL. Eventually one of the disadvantages in these LUS is the use of pesticides for the control of spontaneous plants and pests, which can cause a decline in the diversity of the Collembola community. In fact, some studies, such as Zortéa et al. (2015), show that the springtails may be sensitive to some agrochemicals, such as cypermethrin (pyrethroid), which, through the ecotoxicological leakage test, had a negative effect on the behavior of *F. candida* species. As a result, some species may be more sensitive and others more tolerant, which may determine the dominance of one or a few species in the system.

2. *Analysis of community composition*

The environmental variable TP helps explain the relationship of morphotypes in NF in winter (Figure 2A), and it is influenced by soil management. In most cases, native forests have higher soil TP when compared to areas of reforestation, pasture, and agricultural crops, and this is due to soil conservation and presence of roots in these environments (Loss et al. 2014). In addition, TP is a property that impacts the community of springtails, because these organisms seek shelter and move mainly through the porous structures of the soil (Oliveira Filho & Baretta 2016). Santos et al. (2018) analyzing Collembola morphotypes in the Eastern region of Santa Catarina, in the same LUSs addressed in this study, also found TP as an explanatory environmental variable in the NF area, although it was in the summer, and they highlighted that the morphotypes of all the eco-morphological groups found associated with NF, are benefited by the best soil TP.

The morphotypes related to NF are also benefited by the explanatory variable moisture. According to Bellini (2016), most of the springtails have intimate affinity and dependence on moist soil, making several species susceptible to drought. Temperature and moisture are factors that influence the ideal habitat and the reproduction and growth rates of individuals, as well as their vertical distribution along the soil profile (Rieff et al. 2014).

In LUS, NT and ICL, pH was the environmental variable that helped explain the abundance of Collembola morphotypes, and it was the LUS that related to most of the morphotypes (Ed6, Ed15, H48, H32, H50, H4, Ep17, Ep9, and Ep5). In these systems, often the pH of the soil is corrected, making it higher than compared to native forest areas, where the soil largely has acidic pH. In addition, the ICL area in Orleans (Table 1) received an application of poultry litter, in which there is a presence of lime, which, when reacted in the soil, results in elevated pH. Besides, pH is also a factor that influences the presence of Collembola species. Antoniolli et al. (2013) found in their study that the decrease of pH (greater acidity), makes the development of springtail in the soil harder. Thus, it explains the presence of most of the Collembola morphotypes found in the LUS, NT, and ICL, which were favored with the soil pH conditions found there.

Regarding the results found in summer (Figure 2B), the environmental variable OM helps to explain the abundance of springtail morphotypes in the NF, considering that some springtail morphotypes are influenced by the quality and quantity of OM in the soil, since they feed on decaying material, that is, they participate in the decomposition of OM and in the nutrient cycling (Berude et al. 2015). The relationship verified by PCA (Figure 2B) between NF, OM and some springtail morphotypes (especially Ed6, Ed15, H57, H46, H25, and Ep21) were also found in the Santos et al. (2018) study in Eastern Santa Catarina, which reinforces that there is a close relationship between the springtails and the organic material deposited in the soil.

In addition to the greater amount of OM offered by the diversity of plant species in the NF, the greater number of roots favors the aggregation of the soil. The mean weight diameter of soil aggregates (MWD) is a measure of soil aggregate stability, which indicates soil resistance to erosion. Thus, soil aggregation is important to favor the presence of springtails, since the soil structure and the habitable porous space are essential in the abundance of edaphic springtails. A habitable porous space for springtails and other edaphic organisms is the one that favors the development of all its morphological structures (Oliveira Filho & Baretta 2016).

In the NF, in addition to OM and MWD, moisture was another variable that influenced some morphotypes of springtails, mainly morphotypes Ed6 and Ed15, part of the edaphic eco-morphological group, most influenced by this environmental variable because they live below 5 cm of soil (Figure 2B). Forest environments provide refuge for the permanence of species more sensitive to the variation of moisture since they present forest cover that protects the soil of high temperatures and loss of moisture.

Still, in the summer, the pH was the environmental variable that appeared associated with the springtails in the PA and NT systems, which were close and related only to the Ep10, H16, and Ep5 morphotypes. However, as mentioned earlier, the springtails may have better development and reproduction in soils with the pH closer to neutrality. Nevertheless, the relationship of the springtails with pH is somewhat complex, since there are different morphotypes, and that they have different capacities and limitations.

Conclusion

The impact of land use systems (LUS) on the morphological diversity of Collembola depends on the intensity of the forest/agricultural practices used, including crop rotation, plant material, and soil preparation.

The LUS that retained the greatest morphological diversity of Collembola were the ICL in the winter and the NF in the summer. The variation of the results between the collection seasons was important to highlight the relevance of analyzing different seasons, considering that food resources and properties such as temperature and soil moisture can be different and interfere in the organism's response.

Environmental variables explained that the presence of springtails morphotypes in summer, regardless of LUS, were OM, Mg/K, pH, MWD, and soil moisture, while in the winter were K, pH, OM, $q\text{CO}_2$, TP, and soil moisture.

The morphotyping technique, used as an alternative to the traditional taxonomy, proved to be a good tool to study the biological quality of the soil, together with the diversity indexes and multivariate analysis of the data. As advantages of the morphotyping found during this work, we can mention quickness in the identification of the morphotypes; no need for very long and specific training and simple and low-cost materials used to carry out activities.

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Author Contributions

Danielle Cristina Ortiz: contribution in data collection, data analysis and interpretation, text writing and critical review adding intellectual content.

Marcielli Aparecida Borges dos Santos and Luís Carlos Iuñes de Oliveira Filho: contribution in the analysis and interpretation of data, contribution in the critical revision adding intellectual content and writing of the text.

Pâmela Niederauer Pompeo, Júlia Carina Niemeyer, Osmar Klauberg Filho, Carolina Riviera Duarte Maluche Baretta, and Jean Alberto Sampietro: contribution in critical review by adding intellectual content.

Dilmar Baretta: responsible for the sampling of springtails and data collection, substantial contribution to the concept and study design, contribution in the analysis and interpretation of the data and contribution in the critical review adding intellectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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The genera *Bernardia* Houst. ex Mill. and *Tragia* L. (Euphorbiaceae, Acalyphoideae) in Northeastern Brazil

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Abstract: *Bernardia* and *Tragia* are genera of the subfamily Acalyphoideae, with species occurring in tropical and subtropical regions. Studies concerning those genera are scarce in Brazil, including Northeastern Brazil. The present study was designed to study the taxonomy of species occurring there, and provides illustrations, keys, descriptions, and comments concerning taxonomic affinities, as well as information concerning their geographic distributions and environmental preferences. A total of 13 species were encountered, eight of *Bernardia* and five of *Tragia*. Of those, *B. hamadryadica* and *T. cearensis* are endemic to Northeastern Brazil and *B. celastrinea*, *B. pulchella*, and *T. chlorocaulon* are new records for the region. The two genera occur in moist Atlantic forests, in forest borders, and anthropically impacted areas. New occurrences were recorded in all of the states, totaling 21 new records. The principal diagnostic characters for distinguish were: the sexuality of the plant (monoecious or dioecious), the presence of foliar glands, the types of inflorescence and trichomes, and the numbers of stamens. Among the 13 species encountered, six are illustrated here for the first time.

Keywords: *Bernardieae, Floristic, new occurrences, Plukenetieae, Tragiinae.*

Os gêneros *Bernardia* Houst. ex Mill. e *Tragia* L. (Euphorbiaceae, Acalyphoideae) na região Nordeste do Brasil

Resumo: *Bernardia* e *Tragia* são gêneros da subfamília Acalyphoideae com espécies ocorrendo nas regiões tropicais e subtropicais. Estudos referenciando especificamente esses gêneros são escassos no Brasil, incluindo o Nordeste brasileiro. Portanto, o presente trabalho teve como objetivo realizar o estudo taxonômico das espécies ocorrentes na região Nordeste, fornecendo ilustrações, chave de identificação, descrições e breves comentários sobre afinidades taxonômicas, além de dados de distribuição geográfica e ambiente preferencial das espécies. Um total de 13 espécies foi registrado, sendo oito de *Bernardia* e cinco de *Tragia*. Destas, *B. hamadryadica* e *T. cearensis* são endêmicas do Nordeste e *B. celastrinea*, *B. pulchella* e *T. chlorocaulon* são novos registros para a região. Ambos os gêneros predominam em vegetações de Mata Atlântica em bordas de mata e áreas antropizadas. Novas ocorrências foram verificadas em todos os estados, totalizando 21 novos registros. Os caracteres diagnósticos para distinguir as espécies foram a sexualidade da planta (monoicia ou diocia), presença de glândulas foliares, tipo de inflorescência e tricoma, e número de estames. Dentre as 13 espécies encontradas, seis delas foram ilustradas pela primeira vez.

Palavras-chave: *Bernardieae, Florística, novas ocorrências, Plukenetieae, Tragiinae.*

Introduction

The family Euphorbiaceae is one of the most diverse families of Malpighiales, with 6,300 species and 219 genera, occurring predominantly in tropical and subtropical regions (APG IV 2016, Wurdack et al. 2005, Wurdack & Davis 2009). In Brazil, ca. 950 species and 64 genera occur, and they are most common in the Cerrado (Flora do Brasil 2020 under construction). Euphorbiaceae *s.s.* was restricted to the uniovulate subfamilies Acalyphoideae Beilschm. (20 tribes), Cheilosoideae (Müll. Arg.) K. Wurdack & Petra Hoffm. (1), Crotonoideae Burmeist. (12), Euphorbioideae Beilschm. (5) and Peroideae Baill. ex Hassk. (4) (Wurdack et al. 2005). However, subfamilies Cheilosoideae and Peroideae were excluded in the current concept (Wurdack & Davis 2009).

Acalyphoideae is the largest and most complex subfamily of Euphorbiaceae, comprising 99 genera and 3,000 species (Webster 2014). It is separated from the other subfamilies by the absence of milky latex; laticifers usually absent, or if present, non-articulate; and pollen grains binucleate, but other characteristics are also useful. The absence of petals on the staminate and pistillate flowers is common; only a few taxa (*e.g.*, *Chrozophora* Necker ex A. Juss. and *Ditaxis* Vahl ex A. Juss.) have petals at least in staminate flowers. Most seeds do not have a caruncle, and the pollen does not show the *Croton* pattern of sexine ornamentation: tectate with triangular processes frequently forming continuous arrays (Webster 2014, Gillespie & Ambruster 1997). *Bernardia* Houst. ex Mill. and *Tragia* L. are among the most diverse genera, with 68 and ca. 150 species, respectively (Cardinal-McTeague & Gillespie 2016, Govaerts et al. 2000).

Bernardia is the largest genus of tribe Bernardieae Webster and it has a neotropical distribution, with Brazil and Mexico being the main centers of diversity (Webster 1994, Govaerts et al. 2000, Cervantes et al. 2009). Pax & Hoffmann (1914) recognized seven sections for the genus [*Bernardia* sect. *Tyria* (Klotzsch) Müll. Arg., *B.* sect. *Alevia* (Baill.) Müll. Arg., *B.* sect. *Polyboea* (Klotzsch) Müll. Arg., *B.* sect. *Phyllopassaea* Müll. Arg., *B.* sect. *Crassifoliae* Pax et K. Hoffm., *B.* sect. *Passaea* (Baill.) Müll. Arg., and *B.* sect. *Traganthus* (Klotzsch) Müll. Arg.] based on characteristics such as habit, indumentum and leaf venation patterns, along with stamen, receptacle, and style morphology.

Bernardia is represented in Brazil by 22 species that are distributed mostly in the Southeast, in areas of Cerrado (neotropical savanna) vegetation and Atlantic Forest. Seven species occur in Northeastern Brazil [*Bernardia axillaris* (Spreng.) Müll. Arg., *B. gambosa* Müll. Arg., *B. hamadryadica* J.F. Carrión & Cordeiro, *B. major* (Müll.Arg.) Pax & K.Hoffm., *B. scabra* Müll. Arg., *B. sidoides* (Klotzsch) Müll. Arg., and *B. tamanduana* (Baill.) Müll. Arg.] (Carrión 2018).

Tragia is the largest genus of the tribe Plukenetieae (Benth.) Hutch. and subtribe Tragiinae Webster (Cardinal-McTeague & Gillespie 2016). It has a pantropical distribution, with its principal centers of diversity in the Americas and Africa (Webster 2014). Pax & Hoffmann (1919) initially recognized nine sections for the genus [*T.* sect. *Zuckertia* (Baill.) Müll. Arg., *T.* sect. *Bia* (Klotzsch) Müll. Arg., *T.* sect. *Leucandra* (Klotzsch) Müll. Arg., *T.* sect. *Eutragia* Müll. Arg., *T.* sect. *Ratiga* Müll. Arg., *T.* sect. *Agirta* Baill., *T.* sect. *Ctenomeria* (Harv.) Benth. *T.* sect. *Tagira* Müll. Arg., and *T.* sect. *Lassia* (Baill.) Müll. Arg.] based on sepal morphology, presence of a glandular disk, filament and anther morphology, and the number of stamens. A new section (*T.* sect. *Monadelphae* L.J. Gillespie) was added later (Gillespie 1994a), and some of the existing sections (*T.* sect. *Bia*, *T.* sect. *Ctenomeria*, *T.* sect. *Zuckertia*) were elevated to the category of genus (Webster 2007, 2014, Medeiros et al. 2013).

Sixteen species of *Tragia* occur in Brazil, distributed throughout the country, although more common in the Atlantic Forest. The genus is represented by five species in Northeastern Brazil (*Tragia bahiensis* Müll. Arg., *T. cearensis* Pax & K. Hoffm., *T. cuneata* Müll. Arg., *T. friesii* Pax & K. Hoffm. and *T. volubilis* L.) (Flora do Brasil 2020 under construction).

The two genera can be distinguished by their habit, breeding system (monoecious or dioecious), types of trichomes and inflorescence. *Bernardia* species are monoecious or dioecious shrubs, with simple or stellate trichomes, and unisexual inflorescences (Webster & Burch 1967, Webster 1994). *Tragia* species are herbaceous vines, monoecious, with simple, urticating trichomes and capitate glands, and bisexual inflorescences (Urtecho 1996, Cardinal-McTeague & Gillespie 2016).

In spite of the great richness and morphological diversity of the species of Euphorbiaceae in Brazil, studies of the genera *Bernardia* and *Tragia* have been very rare there. The treatment of Euphorbiaceae published by Müller Argoviensis (1874) in the *Flora brasiliensis* comprised 16 species of *Bernardia* and 22 of *Tragia*. There are records of species of both genera in floristic surveys undertaken in the Serra do Cipó in Minas Gerais State (Cordeiro 1992), areas of *inselbergs* in Milagres (Carneiro et al. 2002), sandy caatingas both in Bahia State (Sátiro & Roque 2008), and in caatinga vegetation in Porto Folha, Sergipe State (Oliveira 2013). Carrión et al. (2017) recently described *Bernardia hamadryadica* J.F. Carrión & Cordeiro for the Chapada Diamantina (Bahia), the first new species of that genus for South America in 40 years.

Despite recent progress, there has been little research on those two genera in Northeastern Brazil, and few collections are encountered in regional herbaria, moreover there is a lack of taxonomists specialized in these groups, consequently many specimens remain unidentified or misidentified in herbaria. In that context, the present work examined the taxonomy of the species of *Bernardia* and *Tragia* occurring in Northeastern Brazil to contribute to a better understanding of those genera, provide keys, morphological descriptions, illustrations, and data concerning their geographic distributions and preferred habitats, to amplify our knowledge of that region's vegetation and to serve as a basis for future taxonomic revisions.

Materials and Methods

1. *Study area*

Northeastern Brazil is the third largest geographic area in Brazil, covering approximately 1,540,827 km^2 (Schneeberger & Farago 2003). The vegetation there is predominantly caatinga (fully deciduous, thorny, xeric vegetation) but, depending on the landscape and elevation, significant areas of forests (ombrophilous and seasonal), savannas (cerrado), *campos rupestres*, dunes, and mangrove swamps are also present (Barbosa et al. 2006).

Northeastern Brazil is known for its hot, sunny weather, with mean temperatures between 20° and 28°C. It is divided into four sub-regions: the Mid-North, which corresponds to the transition between the Amazon region and the dry *sertão* (also known as the Mata do Cocais); the *sertão* itself, where the climate is semiarid and the vegetation is caatinga; the *agreste*, which corresponds to the transition between the *sertão* and the forest zone; and the forest zone, characterized by abundant rainfall (Vieira et al. 2008).

2. *Taxonomic study*

The present study was based on field collections made between April/2016 and December/2017, concentrated principally in the states of Bahia, Paraíba, Pernambuco, and Sergipe (where the largest numbers of species have been recorded). We also examined approximately 1,000 specimens of *Bernardia* and *Tragia* deposited in the principal herbaria in the northeastern region (ALCB, CEPEC, EAC, , HRB, HUEFS, HUNEB, IAN, IPA, JPB, PEUFR, UFP, and HESBRA and HST of Federal Rural of Pernambuco), as well as in a herbarium in southeastern Brazil (RB); acronyms according to Thiers 2018 (continuously updated). Protologues of all of the species studied were consulted, as well as digitized specimens (especially of the type collections deposited in K [https://www.kew.org/]), NYBG (http://sweetgum.nybg.org/science/vh/), P (http://www.mnhn.fr/fr/collections/ensembles-collections/botanique), and other herbaria material available online on *species*Link (http://www.splink.org.br).

The species were identified using analytical keys from classic publications, regional floras, and taxonomic revisions (*e.g.*, Pax & Hoffmann 1914, 1919, Múlgura & Sanguinetti 1989, Gillespie 1993, 1994a, Urtecho 1996, Gillespie & Armbruster 1997), or by comparisons with protologues and type collections. Standardization of the terminology for the vegetative and reproductive structures of the species was based on Harris & Harris (1994). Croizat (1943) was adopted for the shapes of the foliar basilaminar glands.

Information concerning the geographic distributions of the taxa were ascertained from the aforementioned sources, the site of the Flora do Brasil (http://www.floradobrasil.jbrj.gov.br), as well as observations of the species in the study area; data concerning flowering, fruiting, vegetation types, and soils were extracted from the herbarium specimen labels.

We opted not to treat infraspecific categories for *Bernardia* and *Tragia* because there are many gaps in the available information and ongoing discussions concerning their correct identifications and infraspecific classifications.

Results and Discussion

Thirteen species were recorded in the study area, eight of *Bernardia* and five of *Tragia*, representing 35% of the Brazilian species of *Bernardia* and 31% of *Tragia*. Among the species recorded, seven are endemic to Brazil (*Bernardia axillaris*, *B. celastrinea* (Baill.) Müll. Arg., *B. gambosa*, *B. hamadryadica*, *B. scabra*, *B. tamanduana* and *T cearensis*) and occur in almost all regions of the country. *Bernardia hamadryadica* and *Tragia cearensis* are endemic to Northeastern Brazil. The non-endemic species are found also in Argentina (*T. bahiensis*, *T. volubilis*), Bolivia (*B. pulchella* [Baill.] Müll. Arg., *T. chlorocaulon* Baill., *T. friesii*), and Mexico (*B. sidoides*). *Tragia cuneata* and *B. major* were cited for Northeastern Brazil in Flora do Brasil 2020, but these species were not found in the herbaria. Specimens previously identified as *T. cuneata* are in fact *T. volubilis* (e.g., *Santos, T.S. 423*) or other genera (e.g., *Bia* Klotzsch and *Caperonia* A.St.-Hil.). *Bernardia celastrinea*, *B. pulchella*, and *T. chlorocaulon* are cited here for the first time for that region, thereby increasing the number of species cited in Northeastern for *Bernardia* from seven to nine, and for *Tragia* from four to five. The genus *Bernardia* is most diverse in the state of Bahia (eight species) and *Tragia* is more numerous in the state of Ceará (five species). *Tragia volubilis* stands out as having the widest distribution, found in almost all states in Northeastern Brazil; *Bernardia sidoides* likewise occurs in almost all of those states, with the exception of Maranhão.

New records were encountered for almost all of the states in that region, with 21 new occurrences, such as: *Bernardia axillaris* for Paraíba; *B. celastrinea* and *B. pulchella* for Bahia; *T. cearensis* for Alagoas, Paraíba, Rio Grande do Norte and Sergipe; *T. chlorocaulon* for Maranhão; *T. friesii* for Alagoas, Bahia, Ceará, Sergipe and Paraíba; and *T. volubilis* for Alagoas, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe. New records were encountered principally in caatinga and atlantic forest vegetation, with some occurrences also in cerrado (*T. bahiensis*, *T. chlorocaulon*, and *T. volubilis*), on different types of soils (sandy, clayey, rocky), and in areas with granite or limestone outcrops, being most frequent in open areas such as forest edges and anthropogenically impacted environments at elevations between 22 and 1,010 m above sea level elevation.

The significant number of new records may be related to a previous lack of research on these two genera in Northeastern Brazil, the few collections encountered in regional herbarium and the lack of specialized taxonomists in this group. This shows the importance of this kind of research and the need for new studies in both genera.

The principal diagnostic characteristics of the taxa of *Bernardia* include their habit, the presence or absence of basilaminar glands (when present in different numbers and locations, with some species showing paired glands), phyllotaxy, and the type of the staminate inflorescence. *Tragia* species can be distinguished by their types of trichomes, the number of stamens, and the length of the pedicel of the fruit.

Most of the species of *Bernardia* analysed in the study area belong to section *Polyboea*, with the exception of *B. sidoides* (*B. sect. Traganthus*) and *B. gambosa* (unknown section; Cervantes *et al.* 2009). All of the species of *Tragia* treated belong to section *Tragia* (Múlgura & Sanguinetti 1989, Cardinal Mc-Teague & Guillespie 2016), which were currently included into the new circumscription of *Tragia s.l.* (Romero e Sanguinetti 1989; Cardinal Mc-Teague e Guillespie 2016).

Among the species encountered in the study area, six had never been previously illustrated (*Bernardia celastrinea*, *B. gambosa*, *B. scabra*, *B. sidoides*, *B. tamanduana*, and *Tragia cearensis*) here for the first time.

Key to the genera *Bernardia* and *Tragia*

1. Erect plants; branches covered with simple trichomes; inflorescences unisexual; staminate flowers with 5–12 stamens; seeds cordiform or ellipsoid, carinate, testa crustaceous, smooth .... 1. *Bernardia*

1'. Climbing plants; branches covered with urticating trichomes, sometimes simple, tector and capitate glandular; inflorescences bisexual; staminate flowers with 2–3 stamens; seeds spherical, not carinate, testa verrucose, papillose or smooth .... 2. *Tragia*

Taxonomic Treatment

1. ***Bernardia*** Houst. ex Mill., Gard. Dict. Abr. (ed. 4) vol. 1. 1754.

Herbs to shrubs, erect, monoecious or dioecious; branches cylindrical or slightly canaliculate, ramified; indumentum composed of simple trichomes present on vegetative and/or reproductive structures. Leaves alternate or verticillate, petiolate to subsessile, stipulate, simple, entire, the margin crenate or serrate, venation semicraspedodromous; basilaminar glands frequently present, paired or not. Inflorescence unisexual, staminate flowers in pseudoracemes and pistillate flowers in spike or umbelliform; bracts persistent; staminate flowers pedicellate, apetalous; sepals 3, valvate, stamens 5-12, anthers broadly elliptic, basifixed; pistillate flowers sessile on the bract, apetalous, sepals 5, imbricate, entire, ovary 3-carpelar, locules 1-ovulate, styles 3, bifid. Fruits capsules 3-lobed, subglobose, slightly to densely pilose, not corniculate, dehiscent or indehiscent; carpophore not persistent. Seeds cordiform or ellipsoid, ecarunculate, carinate, testa crustaceous, variegated or not, smooth.

Key to the species of *Bernardia* occurring in Northeastern Brazil

1. Plants herbaceous; leaves verticillate; basilaminar glands absent on the leaves …….. 1.7 *B. sidoides*
1'. Plants shrubby; leaves alternate; basilaminar glands present on the leaves
    2. Leaves obovate with margin serrate only on the distal half; basilaminar glands paired
        3. Stipules lanceolate; leaf blade 2–3.5 cm long; basilaminar glands prominent; staminate inflorescences 0.7–1 cm long .... 1.4 *B. hamadryadica*
        3'. Stipules deltate; leaf blade 5.8–12.8 cm long; basilaminar glands not prominent; staminate inflorescences 2–4 cm long .... 1.5 *B. pulchella*
    2'. Leave elliptic, with margin completely serrate; basilaminar glands unpaired
        4. Branches incanous
            5. Stipules lanceolate, incanous; leaf blade incanous; ovary and styles velutinous; seeds ellipsoid, variegate, brown with black splotches ..……..........………………………… 1.6 *B. scabra*
            5' Stipules deltate, strigose; leaf blade glabrescent; ovary pilose; styles glabrescent; seeds cordiform, not variegate, black ....…...…… 1.8 *B. tamanduana*
        4'. Branches strigose, velutinous or pubescent on the youngest branches and pilose on the oldest
            6. Stipules lanceolate or lanceolate to narrow-triangular; leaves pubescent or with abaxial surface pubescent and adaxial surface pilose only on the central vein and margins; stamens 5–8; capsule 3.5–8 mm diam.; seeds light brown or dark brown with black splotches
                7. Branches pubescent on the youngest portion and pilose on the oldest; stipules lanceolate; leaf blade with apex cuneate, abaxial surface pubescent and adaxial surface pilose only on the central vein and margins; ovary incanous; styles glabrescent; capsule 5–8 mm diam., incanous; seeds cordiform, variegated, dark brown with black splotches .... 1.1 *B. axillaris*
                7'. Branches velutinous; stipules lanceolate to narrow-triangular; leaf blade with apex attenuate, pubescent with trichomes distributed principally along the veins; ovary velutinous; styles pilose; capsule 3.5–5 mm diam., velutinous; seeds ellipsoid, not variegated, light brown .. 1.2 *B. celastrinea*
            6'. Stipules deltate; leaves glabrescent; stamens 10–12; capsule 13–14 mm diam.; seeds black without splotches .. 1.3 *B. gambosa*

1.1 ***Bernardia axillaris*** (Spreng.) Müll. Arg., Linnaea 34: 174. 1865.
Figure 1A-H
Shrubs ca. 2 m tall, dioecious; branches pubescent on the youngest branches and pilose on the oldest. Stipules 1.8–2 mm long, lanceolate, pubescent. Leaves alternate; petiole 1–2.5 mm long, pubescent; blade 4.5–6 × 1.2–2 cm, elliptic, base cuneate, apex cuneate, margin completely serrate, abaxial surface pubescent, adaxial surface pilose only on the central vein and margins, basilaminar glands 3–4, not prominent, unpaired. Staminate inflorescence axillary, 2–3 mm long; bracts 0.8–1 mm long, broadly elliptic to ovate, pilose. Pedicel 1–1.2 mm long; sepals 0.8–1 mm long, lanceolate, pilose; stamens 5–6, filaments 0.2–0.3 mm long. Pistillate inflorescence axillary, spicate, 0.7–10 mm long; bracts 1–1.3 mm long, elliptic to ovate, incanous. Sepals 1–1.2 mm long, elliptic to ovate, incanous; ovary globose, incanous; styles glabrescent. Capsule 5–8 mm diam., incanous. Seeds 4–5 mm long, cordiform, variegated, dark brown with black splotches.
Material selected: BRAZIL, BAHIA: Cruz das Almas, 12º67'00" S and 39º10'18" W, 27.V.2012, fl., *A.F.P. Machado 1136* (HUEFS). PARAÍBA: Matureia, 07º18'61" S and 37º43'13" W, 12.VII.1997, fl., *M.F. Agra 4044* (MO).

Bernardia axillaris is considered endemic to Brazil, known from the states of Bahia, Espírito Santo, and Rio de Janeiro, in the Atlantic Forest domain (Carrión 2018). The species is recorded here for the first time for Paraíba State, where it occurs in caatinga vegetation. In the study area, it was found principally in the Atlantic Forest on clayey soils, between 146 and 1,010 m elevation, flowering and fruiting all year.

It is very similar to *B. scabra* by its leave elliptic, with margin completely serrate. However, these species can be distinguished by the number of leaf glands (3–4 glands in *B. axillaris vs.* 9–12 in *B. scabra*). Additionally, the styles of *B. axillaris* are glabrescent while those of *B. scabra* are velutinous. The number of stamens can also distinguish these taxa (5–6 stamens in *B. axillaris vs.* 7–8 in *B. scabra*).

1.2 ***Bernardia celastrinea*** (Baill.) Müll. Arg., Prodr. 15(2): 921. 1866.
Figure 1I-N
Shrubs ca. 1 m tall, dioecious; branches velutinous. Stipules 2.5–3 mm long, lanceolate to narrow-triangular, velutinous. Leaves alternate; petiole 1.5–3 mm long, velutinous; blade 6.5–8.5 × 1.8–2.5 cm, elliptic, base cuneate, apex attenuate, margin completely serrate, pubescent, with trichomes distributed principally along the veins, basilaminar glands 3–5, not prominent, unpaired. Staminate inflorescence axillary, in short pseudoracemes, 6–9 mm long; bracts 2–2.5 mm long, broadly elliptic to ovate, pubescent. Pedicel 0.8–1 mm long; sepals 0.7–0.8 mm long, lanceolate to ovate, pubescent; stamens 6–8, filaments 0.1–0.2 mm long. Pistillate inflorescences axillary, spicate, 0.6–0.8 mm long; bracts 1.8–2 mm long, lanceolate to ovate, pubescent. Sepals 1.8–2 mm long, ovate, pubescent; ovary globose, velutinous; styles pilose.

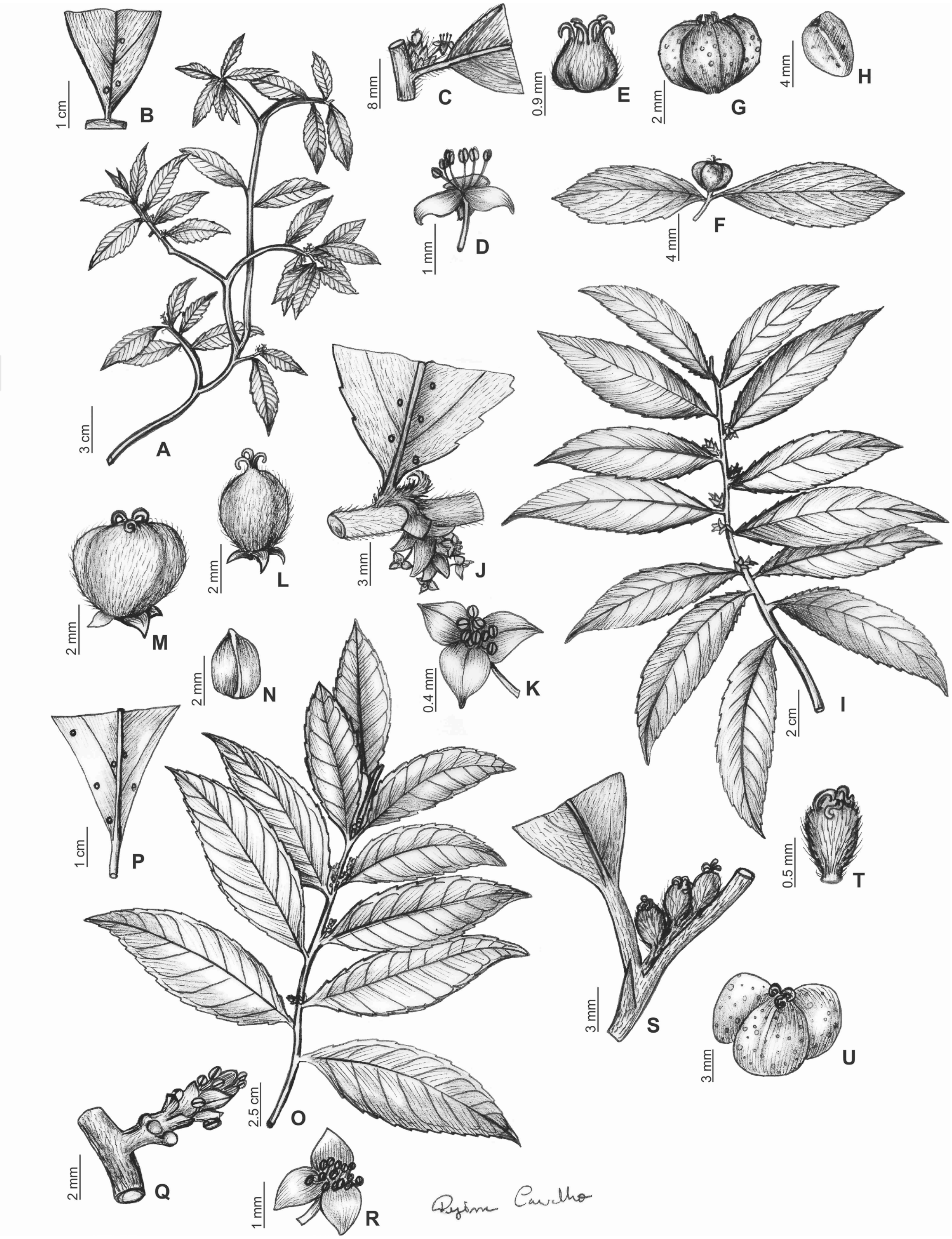

Figure 1. A-H: *Bernardia axillaris*. A: Branch. B: Base of the blade showing basilaminar glands. C: Staminate inflorescence. D: Staminate flower. E: Pistillate flower. F: Branch with fruit. G: Fruit. H: Seed. A-E (*A.F.P. Machado 1136*) and F-G (*S.S. Simões 151*). I-N: *B. celastrinea* (*T.S. Santos 1252*). I: Habit. J: Staminate inflorescence and basilaminar glands not paired. K: Staminate flower. L: Pistillate flower. M: Fruit. N: Seed. O-U: *B. gambosa*. O: Branch. P: Base of the blade showing basilaminar glands. Q: Staminate inflorescence. R: Staminate flower. S: Pistillate inflorescence. T: Pistillate flower. U: Fruit. O-T (*L.M.N. Meyer et al. 8*) and U (*P. Fiaschi et al. 1698*).

Capsule 3.5–5 mm diam., velutinous. Seeds 2–3 mm long, ellipsoid, not variegated, light brown.

Material examined: BRAZIL, BAHIA: Ipiaú, 14º13'72" S and 39º73'39" W, 31.X.1970, fl. and fr., *T.S. Santos 1252* (CEPEC).

Additional Material: BRAZIL, RIO DE JANEIRO: Rio de Janeiro, 22º54'12" S and 43º12'27" W, 18.IX.1946, fl., *P. Occhioni 698* (RB).

The species is endemic to Brazil, occurring in ombrophilous Atlantic Forest vegetation in the states of Rio de Janeiro and São Paulo (Carrión 2018). It is recorded here for the first time in Northeastern Brazil, in Bahia State, were it grows in Atlantic Forest on clayey soils at 153 m elevation. Flowering and fruiting most of the year.

Bernardia celastrinea can be recognized by having staminate inflorescences in pseudoracemes, fruits up to 5 mm diam., and seeds light brown. Among the species found in Northeastern Brazil was possible to observe monoecious individuals of *B. celastrinea* and *B. pulchella*, but *B. celastrinea* has elliptic leaves, the margin completely serrate, and 3–5 unpaired glands, contrasting with *B. pulchella* which has leaves obovate, the margin serrate only on the distal half, and only two paired glands.

1.3 ***Bernardia gambosa*** Müll. Arg., Fl. Bras. 11 (2): 391. 1874.

Figure 1O-U

Shrubs ca. 2 m tall, dioecious; branches strigose. Stipules 1–2.5 mm long, deltate, strigose. Leaves alternate; petiole 0.5–12 mm long, strigose; blade 12–22.5 × 5.5–11 cm, elliptic, base cuneate, apex cuneate, margin completely serrate, glabrescent, basilaminar glands 6–12, not prominent, unpaired. Staminate inflorescence axillary, 1.5–2.5 cm long; bracts 0.5–1 mm long, broadly elliptic to ovate, strigose. Pedicel 1.5–2 mm long; sepals 1–1.5 mm long, ovate, pubescent; stamens 10–12, filaments 0.2–0.3 mm long. Pistillate inflorescence terminal, spicate, 0.7–13 mm long; bracts 1.5–2 mm long, ovate, strigose. Sepals 1–1.2 mm long, ovate, strigose; ovary subglobose, strigose; styles strigose. Capsule 13–14 mm diam., strigose. Seeds 5–7 mm long, cordiform, not variegated, black.

Material examined: BRAZIL, BAHIA: Buerarema, 15º5' S and 39º19' W, 15.X.2003, fr., *P. Fiaschi et al. 1698* (CEPEC).

According to Carrión (2018), *B. gambosa* is endemic to Brazil and its occurrence has been confirmed for Bahia State, with a possible occurrence in Rio de Janeiro (Southeast region). The species is found in Atlantic Forest vegetation in areas of semi-deciduous seasonal and ombrophilous forests. In the study area, it has also been observed in areas of caatinga and areas of restinga vegetation on clayey soils at altitudes between 22 and 400 m elevation. Flowers and fruits were encountered most of the year.

Among the species in the study area, it has the largest leaves (12–22.5 × 5.5–11 cm *vs.* 2–12.5 × 0.5–3.5 cm in the other species), and the largest number of stamens, 10–12 (*vs.* up to nine in the other species). It is similar to *B. tamanduana* by having elliptic leaves with up to 12 unpaired basilaminar glands, but differing by the length of its leaves, number of stamens, and indumentum on the style. *Bernardia tamanduana* has leaves up to 14.2 cm long, only 6 to 8 stamens, and styles glabrescent (*vs.* leaves up to 22.5 cm long, 10 to 12 stamens, and styles strigose in *B. gambosa*).

1.4 ***Bernardia hamadryadica*** J.F. Carrión & Cordeiro, Phytotaxa 317 (1): 69-75. 2017.

Shrubs ca. 1.7 m tall, dioecious; branches slightly canaliculate, pilose. Stipules 3–4 mm long, lanceolate, pilose. Leaves alternate; petiole 2–3 mm long, hirsute; blade 2–3.5 × 0.5–1.5 cm, obovate, base cuneate, apex cuneate, margin serrate only on the distal half, abaxial surface hirsute, adaxial surface pilose, basilaminar glands 3–5, prominent, unpaired. Staminate inflorescences axillary, 0.7–1 cm long; bracts 1.2–1.3 mm long, ovate, pubescent. Pedicel 2–4 mm long; sepals 1–1.2 mm long, lanceolate, pubescent; stamens 6–8, filaments 0.6–0.8 mm long. Pistillate inflorescences axillary, spicate, 5–6 mm; bracts 2–2.5 mm long, ovate, pubescent. Sepals 1–1.2 mm long, ovate, pubescent; ovary globose, velutinous; styles pilose. Capsule 7–10 mm diam., velutinous. Seeds 3.2–4 mm long, cordiform, not variegated, light brown.

Material examined: BRAZIL, BAHIA: Rio de Contas, 13º49'34" S and 41º35'4" W, 5.XII.2004, fl., *R.M. Harley 55283* (HUEFS).

This species is endemic to Bahia State (Carrión 2018), where it occurs in caatinga, carrasco, and deciduous forests (Carrión et al. 2017). It grows on soils with limestone, quartzite, and metamorphic sandstone rock outcrops in the study area, at elevations varying between 534 and 970 m elevation. Flowers and fruits were found in April and December.

It is morphologically similar to *B. pulchella* by the shape and margin of the leaves. However, *B. hamadryadica* has leaves up to 3.5 cm long and with three to five prominent basilaminar glands (*vs.* leaves up to 12.8 cm long and with two non-prominent basilaminar glands).

Illustration: Carrión et al. (2017)

1.5 ***Bernardia pulchella*** (Baill.) Müll. Arg., Fl. Bras. 11 (2): 392. 1874.

Figure 2A-F

Shrubs ca. 2 m tall, dioecious; branches strigose. Stipules 2–3 mm long, deltate, strigose. Leaves alternate; petiole 0.3–5 mm long, strigose; blade 5.8–12.8 × 1.6–3.3 cm, obovate, base acute, apex acute, margin serrate only on the distal half, pubescent, basilaminar glands 2, not prominent, paired. Staminate inflorescences axillary, 2–4 cm long; bracts 0.7–1 mm long, ovate, strigose. Pedicel 0.8–1.2 mm long; sepals 0.8–1 mm long, ovate, pilose; stamens 6–8, filaments 0.1–0.2 mm long. Pistillate inflorescences terminal, spicate, 1–1.6 cm long; bracts 2.5–3 mm long, ovate, pilose. Sepals 1–1.2 mm long, ovate, pubescent along the margin; ovary globose, velutinous; styles connate half their length, pilose. Capsule 3–5 mm diam., velutinous. Seeds 1.8–3 mm long, cordiform, not variegated, dark brown.

Material selected: BRAZIL, BAHIA: Cruz das Almas, 12º40'13" S and 39º06'06" W, XII.1950, fr., *G. Pinto 641* (RB).

This species occurs in Bolivia and in Brazil (Jorgensen et al. 2014), where it has been cited for the states of Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraná, Rio Grande do Sul, Santa Catarina, and São Paulo, being common in the Atlantic Forest in areas of gallery forest, ombrophilous forest, and mixed ombrophilous forest, and in anthropogenically altered environments (Carrión 2018). *Bernardia pulchella* is cited here for the first time for Northeastern Brazil, where to date it is has been found in Bahia State. It grows in Atlantic Forest vegetation on clayey soils, at elevations between 108 and 220 meters elevation. Flowers were observed in November and fruits in December.

Figure 2. A-F: *Bernardia pulchella* (*J. Bueno* 14). A: Branch. B: Base of the blade, showing basilaminar glands. C: Staminate inflorescence. D: Staminate flower. E: Pistillate flower. F: Fruit. G-O: *B. scabra* (*A.M. Carvalho & J. Catti 742*). G: Branch. H: Leaf. I: Base of the blade showing basilaminar glands. J: Staminate inflorescence. K: Staminate flower. L: Pistillate inflorescence. M: Pistillate flower. N: Fruit. O: Seed. P-U: *B. sidoides* (*R.A. Silva 657*). P: Habit. Q: Staminate and pistillate inflorescences. R: Staminate flower. S: Pistillate flower. T: Fruit. U: Seed. V-C': *B. tamanduana*. V: Branch. W: Base of the blade showing basilaminar glands. X: Staminate inflorescence. Y: Staminate flower. Z: Pistillate flower. A': Branch with fruit. B': Fruit. C': Seeds. V-Z' (*A.G. Silva et al. 218*) and A'-C' (*D. Cardoso 1215*).

Bernardia pulchella is morphologically similar to *B. hamadryadica* by its obovoid leaves that are serrate only along the distal half, and paired glands. The distinctions between those two species were discussed in the commentaries concerning *B. hamadryadica*.

1.6 ***Bernardia scabra*** Müll. Arg., Fl. Bras. 11 (2): 396. 1874.
Figure 2G-O
Shrubs ca. 2.5 m tall, dioecious; branches incanous. Stipules 2–2.8 mm long, lanceolate, incanous. Leaves alternate; petiole 3–5 mm long, pubescent; blade 7–12.5 × 3–3.5 cm, elliptic, base cuneate, apex attenuate, margin completely serrate, incanous, basilaminar glands 9–12, not prominent, unpaired. Staminate inflorescences axillary, 4–6 mm long; bracts 1–1.2 mm long, broadly elliptic, pubescent. Pedicel 1–1.2 mm long; sepals 0.9–1 mm long, lanceolate to ovate, pubescent; stamens 7–8, filaments 0.2–0.3 mm long. Pistillate inflorescences axillary, spicate, 0.4–12 mm long; bracts 1–1.2 mm long, lanceolate to ovate, pubescent. Sepals 0.9–1 mm long, lanceolate to ovate, pubescent; ovary globose, velutinous; styles connate at base, velutinous. Capsule 5–10 mm diam., velutinous. Seeds 4–6 mm long, ellipsoid, variegated, brown with black splotches.
Material selected: BRAZIL, BAHIA: Arataca, 15º10’42” S and 39º20’9” W, 12.X.2008, fl., *A.B. Jardim et al. 119* (RB).

According to Carrión (2018), *B. scabra* is known only from Northeastern Brazil, in Bahia State, with possible occurrence in Rio de Janeiro in Southeastern Brazil; it is common in areas of semi-deciduous seasonal and ombrophilous forests. It was also encountered in gallery forests, restinga, and humid forest sites on clayey soils, at elevations between 40 and 860 m elevation. Flowers were observed in October and fruits in December.

Bernardia scabra is characterized by leaves with apex attenuate, 9 to 12 unpaired basilaminar glands, and styles velutinous. Pistillate inflorescences axillary, spicate, leaves elliptic and glands not paired make it morphologically similar to *B. axillaris*. The distinctions between those two species are discussed under *B. axillaris*.

1.7 ***Bernardia sidoides*** (Klotzsch) Müll. Arg., Linnaea 34: 177. 1865.
Figure 2P-U
Herbs ca. 50 cm tall, erect, monoecious; branches pubescent. Stipules 0.8–1 mm long, narrow elliptic to lanceolate, pilose. Leaves verticillate; petiole 0.5–1 cm long, pubescent; blade 4.5–6.7 × 2.4–2.6 cm, elliptic, base cuneate, apex cuneate, margin completely serrate, abaxial surface pilose on the veins, adaxial surface pilose, basilaminar glands absent. Staminate inflorescences terminal, 3–4 mm long; bracts broadly elliptic, pilose. Pedicel 0.5–1 mm long; sepals 0.2–0.3 mm long, lanceolate to ovate, glabrescent; stamens 5, filaments 0.1–0.2 mm long. Pistillate inflorescences terminal, spicate, 5–7 mm long; bracts 1–1.5 mm long, lanceolate to ovate, pilose. Sepals 0.8–1 mm long, lanceolate, pilose; ovary subglobose, pilose; styles hirsute. Capsule 4–6 mm diam., hirsute. Seeds 2.5–3 mm long, ellipsoid, not variegated, dark brown.
Material selected: BRAZIL, ALAGOAS: Piranhas, 9º62’36” S and 37º75’66” W, 27.VII.1999, fl. and fr., *R.A. Silva 657* (PEUFR). BAHIA: Milagres, 12º87’13” S and 39º85’25” W, 13.III.2005, fl. and. fr., *F. França 5173* (HUEFS). PARAÍBA: São José of Piranhas, 7º07’15” S and 38º30’07” W, 19.VII.2008, fl., *J.R. Andrade et al. 96* (PEUFR). PERNAMBUCO: Serra Talhada, 7º59’31” S and 38º17’53” W, 3.V.2017, fl. and fr., *M.O. Santos et al. 45* (HUNEB). PIAUÍ: Cocal, 3º40’83” S and 41º43’58” W, 23.II.2003, fl. and fr., *E.M.F. Chaves 163* (HUEFS). RIO GRANDE DO NORTE: Serra Negra do Norte, 6º58’33” S and 37º23’33” W, 20.V.2005, fl. and fr., *R.T. Queiroz 375* (HUEFS). SERGIPE: Canindé do São Francisco, 9º33’23” S and 37º56’28” W, 28.III.2000, fl. and fr., *R.A. Silva & D. Moura 1431* (PEUFR).

Bernardia sidoides occurs in Brazil, Costa Rica, Guatemala, Guyana, Mexico, Nicaragua, and Venezuela (Cervantes 2006). In Brazil, it has been recorded in the states of Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe in caatinga vegetation, seasonal deciduous forests, and also on rock outcrops (Carrión 2018). Flowers and fruits were recorded throughout the year.

This is the only species in the study area with verticillate leaves. It is also the only herbaceous monoecious plant with staminate and pistillate inflorescences in terminal.

1.8 ***Bernardia tamanduana*** (Baill.) Müll. Arg., Prodr. 15 (2): 920. 1866.
Figure 2V-C’
Shrubs ca. 4 m tall, dioecious; branches incanous. Stipules 2.8–3.1 mm long, deltate, strigose. Leaves alternate, subsessile; petiole 3–5 mm long, strigose; blade 9–14.2 × 3.2–5 cm, elliptic, base cuneate, apex cuneate, margin completely serrate, glabrescent, basilaminar glands 9–12, not prominent, unpaired. Staminate inflorescences axillary, 1–3 cm long; bracts 0.8–1.2 mm long, deltate to ovate, glabrescent. Pedicel 1–1.2 mm long; sepals 0.7–0.8 mm long, lanceolate, pilose; stamens 6–8, filaments 0.1–0.2 mm long. Pistillate inflorescences terminal, spicate, 3–9 mm long; bracts 1–1.2 mm long, ovate, pilose. Sepals 0.8–1 mm long, lanceolate, pilose; ovary globose, pilose; styles connate half their length, glabrescent. Capsule 8–10 mm diam., velutinous. Seeds 3–5 mm long, cordiform, not variegated, black.
Material selected: BRAZIL, ALAGOAS: Santana do Riacho, 19º17’60” S and 43º00’00” W, 20.XII.1974, fl., *A.D. Andrade-Lima 7780* (HUEFS). BAHIA: Almadina, 14º70’53” S and 39º63’72” W, 3.VIII.1971, fl., *R.S. Pinheiro 1537* (CEPEC). CEARÁ: Guaramiranga, 4º26’33” S and 38º93’31” W, 7.I.1994, fl., *M.R. Oliveira s/n (UFP – 52285)*. PARAÍBA: Santana do Riacho, 7º13’60” S and 37º20’59” W, 16.IV.1993, fl., *M.F. Agra 1964* (IPA). PERNAMBUCO: Brejo da Madre de Deus, 8º11’14” S and 36º24’63” W, 19.I.2000, fl., *A.G. Silva et al 218* (CEPEC).

This species is endemic to Brazil (Forzza 2010), in the states of Alagoas, Bahia, Ceará, Minas Gerais, Paraíba, and Pernambuco, where it grows in caatinga, atlantic forest, carrasco, deciduous seasonal forest, and semi-deciduous seasonal forest (Carrión 2018). It has also been observed in Northeastern Brazil in gallery forests, and montane ombrophilous forests on clayey and rocky soils at elevations between 234 and 1,010 m elevation. Flowers and fruits were encountered during the entire year.

Bernardia tamanduana is characterized as a dioecious shrub, ca. 4 m tall, with its inflorescences terminal, spicate. It is morphologically similar to *B. gambosa*; the two species are compared under the latter.

2. ***Tragia*** L., Sp. Pl. 2: 980. 1753.

Climbing herbs, monoecious; branches cylindrical or slightly canaliculate, ramified; indumentum composed of urticating trichomes, tector, simple, and capitate glands. Leaves alternate, simple, entire, the margin serrate, petiolate, stipulate, venation craspedodromous; basilaminar glands absent. Inflorescences bisexual, terminal or axillary, racemose, staminate flowers in distal nodes, solitary, pistillate flowers in proximal nodes, solitary; bracteoles persistent; staminate flowers pedicellate, apetalous, sepals 3, valvate, stamens 2–3, anthers broadly elliptic, basifixed; pistillate flowers pedicellate, apetalous, sepals 6, imbricate, entire, ovary 3-carpelar, generally hispid, urticating, locules 1-ovulate, styles 3, free or united, stigma smooth or papillose. Fruit a capsule 3-lobed, subglobose, pubescent or hirsute, sometimes corniculate, septicidal-loculicidal, carpophore persistent. Seeds spherical, ecarunculate, not carinate, testa variegated or not, verrucose, smooth or tuberculate, sometimes papillose.

Key to the species of *Tragia* in Northeastern Brazil

1. Plants lacking capitate glandular trichomes
    2. Stipules narrowly triangular; styles pilose; seeds black, testa verrucose .... 2.2 *T. cearensis*
    2'. Stipules lanceolate; styles glabrescent; seeds light brown, testa papillose .... 2.5 *T. volubilis*

1'. Plants with capitate glandular trichomes on both vegetative and reproductive parts
    3. Branches pubescent; leaf with attenuate apex; staminate bracts elliptic; styles glabrescent; seeds with papillose testa .. 2.1 *T. bahiensis*
    3'. Branches hirsute or velutinous; leaf with acute apex; staminate bracts lanceolate; styles pubescent or pilose; seeds with smooth or tuberculate testa
        4. Styles pilose; capsule hirsute; seeds with smooth testa, variegated, black with brown splotches .... 2.3 *T. chlorocaulon*
        4'. Styles pubescent; capsule pubescent; seeds with tuberculate testa, not variegated, dark brown, without brown splotches .... 2.4 *T. friesii*

2.1 ***Tragia bahiensis*** Müll. Arg., Linnaea 34: 182. 1865.

Figure 3A-G

Climbing herbs; branches cylindrical, pubescent; trichomes simple, urticating trichomes and capitate glands on the vegetative and reproductive parts. Stipules 1.6–1.8 mm long, lanceolate, pubescent. Petiole 1.5–3 cm long, pubescent; blade 3–9.3 × 1.7–3.9 cm long, lanceolate to ovate, base subcordate to cordate, apex attenuate, abaxial surface pubescent, adaxial surface pilose. Inflorescence axillary, racemose, 1–3.2 cm long; bracts 0.8–1 mm long, elliptic, pilose. In staminate flowers the pedicel 0.6–0.8 mm long; bracteoles 0.8–1 mm long, elliptic, pubescent; sepals 0.7–0.8 mm long, lanceolate, pubescent; stamens 3, filaments 0.1–0.2 mm long. In pistillate flowers the pedicel 1.8–2 mm long; bracteoles 0.8–1 mm long, lanceolate, pubescent; sepals 0.8–0.9 mm long, lanceolate, pubescent; ovary globose, pubescent; styles connate for half their length, glabrescent. Capsule 2–4 mm diam., pedicel 1.8–2 mm long, subglobose, pubescent. Seeds 1–1.2 mm diam., testa papillose, not variegated, dark brown.

Material selected: BRAZIL, BAHIA: Barreiras, 28.XII.1954, fl. and fr., *Black 54-17894* (IAN).

Additional Material: BRAZIL, GOIÁS: Ponte Alta, 14°23,5' S and 48°25,3' W, 5.II.2005, fl. and fr., *Reeves et al. 3035* (CEN). MINAS GERAIS: Monte Azul, 15°12'36" S and 42°53'49" W, 22.IV.2006, fr., *Carneiro-Torres et al. 715* (HUEFS).

This species occurs in Argentina, Bolivia, Brazil, and Paraguay (Múlgura 1991). In Brazil, it is known from the states of Bahia, Mato Grosso, Minas Gerais, Paraná, Rio Grande do Sul, and São Paulo, in the Caatinga and Cerrado domains and in areas of campo limpo (Flora do Brasil 2020 under construction). It grows in arboreal-shrub caatinga vegetation on sandy and rocky soils and on gray limestone outcrops between 60–1,000 m elevation. Individuals with flowers and fruits were collected from April to August.

Tragia bahiensis is characterized principally by having leaves with subcordate to cordate bases, apex attenuate, and fruit with pedicel up to 2 mm long. Additionally, it has simple urticating trichomes and capitate glands on the reproductive and vegetative structures of the plant, like *Tragia friesii*. However, these species can be distinguished by staminate bracts elliptic (*vs*. staminate bracts lanceolate in *T. friesii*), styles glabrescent (*vs.* styles pubescent), and seeds with papillose testa (*vs.* seeds with tuberculate testa).

2.2 ***Tragia cearensis*** Pax & K. Hoffm., Pflanzenr. IV. 147. XVII (Heft 85): 186. 1924.

Figure 3H-K

Climbing herbs; branches cylindrical, slightly canaliculate, hirsute; with simple and urticating trichomes on the vegetative and reproductive parts; glandular trichomes absent. Stipules 2–2.3 mm long, narrowly triangular, pilose. Petiole 1–3.6 cm long, hirsute; blade 6–8.5 × 3–4 cm, ovate-triangular, base cordate, apex attenuated, hirsute. Inflorescence axillary, racemose, 1.2–1.5 cm long; bracts 0.8–1 mm long, lanceolate, pilose. In staminate flowers the pedicel 1–1.3 mm long; bracteoles 0.8–1 mm long, lanceolate, pilose; sepals 0.9–1 mm long, lanceolate, pilose; stamens 3, filaments 0.1–0.2 mm long. In pistillate flowers the pedicel 1–1.2 mm long; bracteoles 0.8–1 mm long, lanceolate, pilose; sepals 0.9–1 mm long, lanceolate, pilose; ovary globose, hirsute; styles connate for half their length, pilose. Fruit 7–8 mm diam., pedicel 1–1.2 mm long, subglobose, hirsute. Seeds 2–2.3 mm diam., testa verrucose, not variegated, black.

Material examined: BRAZIL, ALAGOAS: São José da Tapera, 9º37'34"S and 37º22'42"W,14.VII.2000, fr., *R.P. Lyra-Lemos 4732* (MAC). CEARÁ: Santa Quitéria, 4º35' S and 39º43' W, 24.IV.2012, fl. and fr., *J.P. Souza et al. 10889* (RB). PARAÍBA: Areia, 12.VI.1953, fl. and fr., *J.C. Moraes 1155* (US). RIO GRANDE DO NORTE: Serra Negra do Norte, 6º56'66" S and 37º25' W, 14.IV.2006, fl. and fr., *R.T. Queiroz 677* (HUEFS). SERGIPE: Canindé de São Francisco, 9º65'99" S and 37º78'93" W, 8.IV.2011, fl. and fr., *A.A.B. Silva & M.P. Souza 20* (EAC).

Tragia cearensis is endemic to Brazil and was previously cited only for Ceará State in caatinga vegetation (Flora do Brasil 2020 under construction). It is recorded here for the first time from Alagoas, Paraíba, Rio Grande do Norte and Sergipe, where it grows in Atlantic Forest in canopy gaps and gallery forest vegetation on sandy and clayey soils, at elevations between 60 and 990 meters elevation. Individuals with flowers and fruits were collected from January to July.

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Figure 3. A-G: *Tragia bahiensis* (*Black 54-17894*). A: Branch. B: Leaf. C: Staminate flower. D: Branch with pistillate flower. E: Pistillate flower. F: Fruit. G: Seed. H-K: *T. cearensis* (*R.T. Queiroz 677*). H: Branch. I: Staminate flower. J: Pistillate flower. K: Fruit. L-Q: *T. chlorocaulon* (*G. Eiten & L.T. Eiten 4836*). L: Branch. M: Detail of the stipule. N: Staminate flower. O: Pistillate flower. P: Fruit. Q: Seed.

It is the only species in the present study that presents black verrucose seeds. Additionally, it does not have glandular trichomes, like in *Tragia volubilis*, but only simple and urticating trichomes covering its vegetative and reproductive structures. However, these species can be distinguished by the length of the fruit pedicel (1–1.2 mm in *T. cearencis vs* 1.5–2 cm in *T. volubilis*).

2.3 ***Tragia chlorocaulon*** Baill., Étude Euphorb. 461. 1858.
Figure 3L-Q
Climbing herbs; branches cylindrical, velutinous; with simple and urticating trichomes and capitate glands on the vegetative and reproductive parts. Stipules 4–5 mm long, narrow-triangular to lanceolate, pilose. Petiole 1–2.4 cm long, hirsute; blade 3.5–8.5 × 3.2–8.8 cm, cordiform, base cordate, apex acute, hirsute. Inflorescence axillary, racemose, 4.5–11.5 cm long; bracts 1.9–2 mm long, lanceolate, pilose. In staminate flowers the pedicel 0.8–1 mm; bracteoles 1–1.2 mm long, lanceolate, pilose; sepals 1–1.2 mm, lanceolate, pilose; stamens 3, filaments 0.1–0.2 mm long. Pistillate flowers sessile; bracteoles 1.2–1.4 mm long, lanceolate, pilose; sepals 1–1.3 mm long, pubescent; ovary globose, hirsute; styles connate for half their length, pilose. Capsule 8–10 mm diam., sessile, subglobose, hirsute. Seeds 3–4 mm diam., testa smooth, variegated, black with brown splotches.
Material examined: BRAZIL, MARANHÃO: Loreto, 7º43’33” S and 45º 00’ W, 6.VI.1962, fl. and fr., *G. Eiten & L.T. Eiten 4836* (SP).
Additional Material: BRAZIL, MINAS GERAIS: Carangola, 20º43’59” S and 42º01’46” W, 10.VII.2009, fl. and fr., *F. Marcolino 131* (RB). SÃO PAULO: Barreiro, 22º38’42” S and 44º34’40” W, fl. and fr., *G.E.R.F. Edwall 68* (SP).

This species is recorded from Bolivia and Brazil (Jorgensen et al. 2014). According to Flora do Brasil 2020 (under construction), this species had been observed only in the Central-Western region of Brazil (Federal District and state of Goiás), where it grows in the Cerrado domain. The present study records the species from the states of Maranhão (a new occurrence for that species in Northeastern Brazil), Minas Gerais and São Paulo, growing in cerrado vegetation on clayey soils ca. 250 meters elevation.

Tragia chlorocaulon can be characterized by its cordiform leaves and simple and urticating trichomes and capitate glands on the vegetative and reproductive structures of the plant. The species stands out as being the only one in the study area to have seeds with the testa smooth and variegated, black with brown splotches (*vs*. seeds with testa papillose, verrucose or tuberculate in the other species). It is similar to *T. bahiensis* by its simple and urticating trichomes and capitate glands. However, *T. chlorocaulon* has leaf blade cordiform and hirsute, and the inflorescences 4.5–11.5 cm long (*vs.* lanceolate to ovate, with abaxial surface pubescent and adaxial surface pilose and inflorescences 1–3.2 cm long).

2.4 ***Tragia friesii*** Pax & K. Hoffm., Pflanzenr. IV. 147 XVII (Heft 85): 186. 1924.
Figure 4A-F
Climbing herbs; branches cylindrical, hirsute; trichomes simple, urticant and glandular on the vegetative and reproductive parts. Stipules 2.5–3 mm long, deltate, pilose. Petiole 1.5–2 cm long, hirsute; blade 4–8 × 4.5–5.7 cm, ovate, base cordate, apex acute, pubescent. Inflorescences axillary, racemose, 6–9 cm long; bracts 1–1.2 mm long, lanceolate, pilose. In staminate flowers the pedicel 1–1.2 mm long; bracteoles 0.8–1 mm long, lanceolate, pilose; sepals 1.2–1.3 mm long, lanceolate, pilose; stamens 3, filaments 0.1–0.2 mm long. Pistillate flowers sessile; bracteoles 0.9–1 mm long, narrowly elliptic, pubescent; sepals 0.8–1 mm long, lanceolate, pubescent; ovary globose, pubescent; styles connate at base, pubescent. Capsule 4–6.2 mm diam., sessile, subglobose, pubescent. Seeds 2.5–3 mm diam., testa tuberculate, not variegated, dark brown.
Material examined: BRAZIL, ALAGOAS: Piranhas, 9º62’36” S and 37º75’66” W, 11.VIII.1999, fr., *R.A. Silva 807 & D. Moura* (PEUFR). BAHIA: Milagres, 12º89’16” S and 39º82’58” W, 16.III.1997, fl. and fr., *F. França et al. 2169* (ALCB). PARAÍBA: Queimadas, 7°22’36” and 35°56’41”, 18.IV.2006, fl. and fr., *M.F. A. Lucena & A. Araújo 1315* (UFP). PERNAMBUCO: Ipubi, 7º65’19” S and 40º14’88” W, 15.IV.2010, fr., *A.M. Miranda et al. 6166* (HST). SERGIPE: Porto da Folha, 10°02’21” and 37°24’90”, 14.VI.2006, fl. and fr., *M.F. A. Lucena et al. 1833* (UFP).

Tragia friesii occurs in Bolivia and Brazil (Foster 1958, Múlgura & Sanguinetti 1989). In Brazil, it was only known from Pernambuco State, in the Caatinga domain (Múlgura & Sanguinetti 1989, Flora do Brasil 2020 under construction). It is recorded here for the first time in the states of the Alagoas, Bahia, Paraíba and Sergipe, were it was found growing in Atlantic Forest vegetation, along the edges and interiors of forests, as well as in anthropogenically modified environments on clayey and sandy soils at elevations from 250 to 1,086 m elevation. Flowers and fruits were encountered from January to July.

The species is characterized by having leaves with base cordate and apex acute, and pistillate flowers with pubescent styles. *Tragia friesii* can be confused with *T. bahiensis* since both share glandular trichomes and dark brown seeds. They can be distinguished by the bases and apices of their leaves and the distributions of the glandular trichomes: in *T. bahiensis*, the leaf base is subcordate and the apex attenuate, and glandular trichomes are restricted to the reproductive parts of the plant (*vs*. leaves with base cordate and apex acute, and glandular trichomes on all parts of the plant in *T. friesii*).

2.5 ***Tragia volubilis*** L., Sp. Pl. 2: 980. 1753.
Figure 4G-M
Climbing herbs; branches cylindrical, hirsute; with simple and urticating trichomes on the vegetative and reproductive parts of the plant; glandular trichomes absent. Stipules 2–3 mm long, lanceolate, pilose. Leaves entires; petiole 0.5–1.1 cm long, pubescent; blade 2–3.8 × 1.2–1.6 cm, lanceolate to ovate, base subcordate to truncate, apex attenuate, abaxial surface pubescent, adaxial surface pilose. Inflorescence axillary, racemose, 2–3 cm long; bracts 0.8–1 mm long, narrowly elliptic, pubescent. In staminate flowers the pedicel 0.8–1 mm long; bracteoles ca. 0.5 mm long, lanceolate, pubescent; sepals 0.6–0.9 mm long, lanceolate, pubescent; stamens (2–)3, filaments 0.1–0.2 mm long. In pistillate flowers the pedicel 7–9 mm long; bracteoles 0.6–0.8 mm long, lanceolate, pubescent; sepals 0.6–0.7 mm long, lanceolate, pilose; ovary globose, velutinous; styles connate for half their length, glabrescent. Capsule 2–3 mm diam., pedicel 1.5–2 cm long, globose, pubescent, horns (3) 4–5 mm long. Seeds 1.8–2 mm diam., testa papillose, not variegated, light brown.

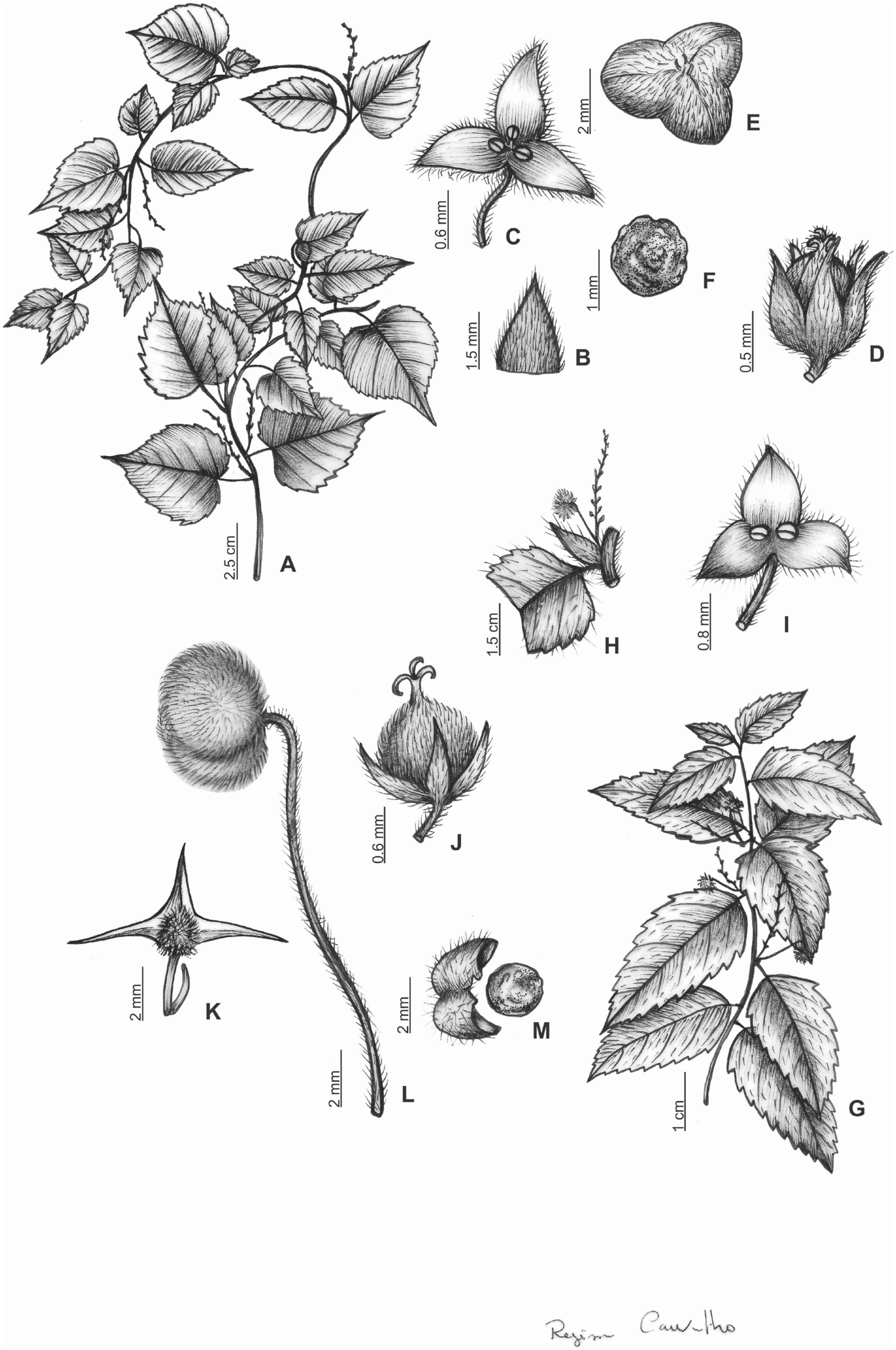

Figure 4. A-F: *Tragia friesii* (*F. França et al. 2169*). A: Branch. B: stipule. C: Staminate flower. D: Pistillate flower. E: Fruit. F: Seed. G-M: *T. volubilis* (*L.P. Queiroz 5965*). G: Branch. H: Bisexual inflorescence. I: Staminate flower. J: Pistillate flower. K: Fruit. L: Fruit. M: Seed.

Material selected: BRAZIL, ALAGOAS: Pão de Açúcar, 9º43'24" S and 37º30'13" W, 21.VI.2002, fr., *R.P. Lyra-Lemos et al. 6774* (RB). BAHIA: Pindobaçu, 10º44' S and 40º21' W, 20.XII.1999, fl. and fr., *M.L. Guedes et al. 6985* (ALCB). CEARÁ: Forquilha, 03° 47'52" S 40° and 15'39" W, 5.IV.1996, fl. and fr., *A.S.F. Castro s.n.* (EAC 24034). MARANHÃO: Loreto, 7º28'33" S and 45º11'66" W, 6.IV.1962, fl. and fr., *G. Eiten & L.T. Eiten 4107* (SP). PARAÍBA: Soledade, 7º05'72" S and 36º36'27" W, 21.V.2006, fl. and fr., *R.F.P. Lucena 225* (PEUFR). PERNAMBUCO: Carnaubeira da Penha, 8º44'41" S and 38º75'52" W, 27.VIII.2014, fl., *Costa-Lima et al. 1633* (RB). PIAUÍ: Floriano, 6º76'69" S and 43º02'24" W, 4.III.2005, fl. and fr., *A.M. Miranda et al. 5038* (HST). RIO GRANDE DO NORTE: Tibau do Sul, 6º14'45" S and 35º3'20" W, 2.VI.2014, fl. and fr., *J.G. Jardim et al.* 6661 (RB). SERGIPE: Indiaroba, 10º30'00" S and 36º24'00" W, 17.IX.2017, fl. and fr., *M.O. Santos 94 & M.M. Costa* (HUNEB).

Tragia volubilis is widely distributed and occurs throughout most of the Neotropics from Argentina to Mexico (Múlgura 1991). In Brazil, it has been cited from the states of Bahia, Rondônia, and São Paulo, being common in amazon forest and upland forests, as well as caatinga and atlantic forest vegetation (Flora do Brasil 2020 under construction). This is the first record of *T. volubilis* for the states of Alagoas, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe, where it was observed in areas of cerrado, gallery forest, and restinga vegetation, as well as in anthropogenically modified environments, growing on clayey an sandy soils, and on limestone rocks at elevations between 180 and 1,000 meters elevation. It has been found flowering and fruiting throughout the year. Among the species studied in the present work, it is the best-represented in all of the herbarium collections of Euphorbiaceae in Northeastern Brazil.

It is easily recognized by the length of the pedicel (to 2 cm), which is frequently as long as the peduncle. Adictionally, the presence of monospermic fruits, with three very evident horns, as well as normal tricoccal fruits that also have small horns (although they are inconspicuous).

List of collectors

Agra, M. F. 2961 (1.7), 1964 (1.8), 2667 (1.8), 4044 (1.8). **Alves, L. J.** 420 (1.6), 426 (1.6). **Amorim, A. M.** 7694 (1.6), 4084 (1.8), 9146 (2.5), 9372 (2.5). **Andrade, J. R.** 96 (1.7), 172 (1.7). **Andrade-Lima, A. D.** 7780 (1.8). **Aona, L. Y. S.** 2423 (1.6), 2492 (1.6). **Araújo, D.** 604 (2.5), 1084 (2.2), 1465 (2.2), 4334 (2.5), 5045 (2.5), 10002 (2.5). **Araújo, E. L.** 445 (1.7), 437 (2.5). **Araújo, F. S. 31** (1.7), 1339 (1.7). **Arouck-Ferreira, J. D. C.** 250 (2.5). **Bacelar, T. G.** 16 (1.6). **Barros, A. A. M.** 1757 (1.1), 2095 (1.1), 3118 (1.1). **Bautista, H. P.** 1220 (1.5), 1224 (2.5). **Belém, R. P.** 2912 (1.5). **Bovini, M. G.** 1771 (1.2). **Brade, A. C.** 12824 (2.5), 19622 (2.5). **Brito, N. M. P.** 78 (2.5). **Brito, T. H.** 4072 (1.6). **Bueno, J.** 14 (1.5). **Calliari, C. P.** 2203 (1.5). **Carauta, P.** 396 (1.1), 1264 (2.5). **Cardoso, D.** 1215 (1.8), 1702 (1.8). **Carneiro-Torres, D. S.** 715 (2.1). **Carrión, J. F.** 1730 (1.4), 1731 (1.4), 1732 (1.4). **Carvalho, A. M. V.** 743 (1.3), 652 (1.6), 742 (1.6), 1149 (1.6), 1528 (2.5). **Carvalho-Sobrinho, J. G.** 130 (1.8). **Castro s.n.** (2.1). **Cavalcanti, G.** 34 (2.2). **Caxambu, M. G.** 1500 (2.5). **Chaves, E. M. F.** 163 (1.7). **Conceição, S. F.** 69 (2.5). **Constantino, D.** 1917 (1.1). **Cordeiro, J.** 1132 (1.5), 1588 (1.5). **Costa, E. L.** 212 (1.1). **Costa, K. C.** 132 (1.7), 361 (1.7). **Costa, M. A. A.** 223 (1.3), 67 (2.5). **Costa-Lima, J. L.** 1633 (2.5). **Couto, A. P. L.** 29 (2.5). **Damascena, L.** 174 (2.5). **Daneu, L.** 238 (1.6), 532 (1.6). **Dantas, R.** 63 (1.7). **Delgado-Júnior, G. C.** 604 (2.4), 688 (2.4). **Dreveck, S.** 174 (1.5). **Duarte, A. P.** 932 (1.1), 5203 (1.2), 1766 (1.5), 5394 (2.5), 6089 (2.5). **Edwall, G. E. R. F.** 68 (2.3). **Eiten, G.** 4836 (2.3), 4107 (2.5). **Falcão, J.** 43 (1.5), 187 (1.5). **Farág, P. R. C.** 374 (1.1). **Faria, G. A.** 119 (2.5). **Farney, C.** 3603 (1.1), 3816 (1.1), 3842 (1.1), 3933 (1.1), 4119 (1.1), 4387 (1.1), 4490 (1.1). **Félix, L. P.** 6555 (2.2). **Fernandes, A.** s.n. (2.5). **Fernandes, D.** 233 (1.1). **Ferraz, E.** 39 (1.8). **Ferreira, P. A.** 102 (1.6). **Ferreira, V. F.** 2117 (2.5). **Fiaschi, P.** 1698 (1.3), 1715 (1.3), 2740 (1.8), 2762 (1.8). **Figueiredo, M. A.** s/n. (2.2). **Filho, W. M. B.** 6 (2.5). **Fotius, G.** 3823 (1.7). **França, F.** 2558 (1.5), 5173 (1.7), 3054 (1.8), 2169 (2.5), 2137 (2.5). **Furtado, P. P.** 143 (1.5). **Gasper, A. L.** 3133 (1.5). **Geraldino, H. C. L.** 311 (1.5). **Giordano, L. C.** 1414 (1.1). **Gomes, F. S.** 633 (2.5), 1005 (2.5). **Guedes, M. L.** 12713 (1.6), 6985 (2.5), 6895 (2.5), 9541 (2.5), 12040 (2.5), 14042 (2.5), 14186 (2.5), 14689 (2.5), 16713 (2.3), 17079 (2.5), 18355 (2.5), 19926 (2.5), 21186 (2.5). **Haje, J. L.** 1470 (2.5), 1710 (2.5). **Harley, R. M.** 55283 (1.4), 3405 (1.7), 18986 (1.7), 56379 (1.7), 16499 (2.5). **Hatschbach, G.** 67155 (1.5), 76822 (1.5). **Hurbath, F.** 526 (1.8). **Jardim, A. B.** 119 (1.6). **Jardim, J. G.** 493 (1.6), 4501 (1.8), 4750 (1.8), 6661 (2.5), 5548 (2.2). **Jesus, J. A.** 481 (2.5). **Jesus, N. G.** 920 (2.5). **Kinupp, V. F.** 198 (1.5). **Korte, A.** 6610 (1.5). **Krieger, L.** 7224 (2.5). **Kuhlmann, J. G.** 824 (2.5). **Laurênio, A.** 480 (1.7), 725 (1.7), 779 (1.7), 858 (1.7), 897 (1.7), 3705 (2.2). **Leoni, L. S.** 1122 (2.3), 2819 (2.3). **Lima, A.** 3068 (2.5). **Lima, D. F. S.** 6 (1.5). **Lima, G. C.** 40 (1.7), 53 (2.4). **Lima, J. A.** 55 (2.5). **Lima, J. C. A.** 261 (1.8). **Lima, S. T. C.** 13 (2.5). **Lima, V. C.** 131 (2.5), 257 (2.5). **Lindeman, J. C.** 1312 (1.5). **Lins, A. C. B.** 272 (1.7). **Lisboa, M. S.** 292 (2.5). **Lopes, C. G.** 513 (1.8). **Loureiro, D. L.** 525 (1.3), 763 (1.3). **Lucena, D. S.** 535 (2.5), 559 (2.5), 626 (2.5), 643 (2.5). **Lucena, M. F. A.** 803 (1.7), 1160 (1.7), 1751 (1.7), 1754 (1.7), 1186 (2.4), 1315 (2.4), 1418 (2.4), 1435 (2.4), 1468 (2.5), 1522 (2.5), 1533 (2.5), 1713 (2.2), 1833 (2.4), 1849 (2.4). **Lucena, R. F. P.** 225 (2.5). **Lyra-Lemos, R. P.** 6774 (2.5). **Lyra-Lemos, R. P.** 6774 (2.5). **Macedo, G. E. L.** 165 (2.5). **Machado, A. F. P.** 1136 (1.1). **Machado, R. F.** 539 (1.7), 149 (2.4). **Maciel, J. R.** 982 (1.7), 868 (2.5). **Maciel-Júnior, L.** 220 (1.7). **Marcolino, F.** 131 (2.3). **Marques, M. C.** 180 (1.1). **Marquete, R.** 481 (1.1), 2358 (1.1), 2361 (1.1), 326 (2.5). **Martinelli, G.** 18324 (1.8), 3129 (2.5). **Martins, M. L. L.** 1908 (1.8), 1910 (1.8), 1914 (1.8). **Mata, M. F.** 1994 (1.7), 197 (2.5). **Matos, S. S.** 224 (1.7). **Mattos-Silva, L. A.** 4020 (1.6), 4535 (1.6), 4554 (1.6), 156 (2.5). **Melo, E.** 5506 (1.4), 5512 (1.4), 1928 (1.7), 2088 (1.7), 4786 (1.8), 4789 (1.8), 5163 (2.5), 6270 (2.5). **Melo, P. H. A.** 203 (1.8), 1241 (1.8), 1373 (1.8). **Melquíades, A.** 51 (1.7). **Menezes, L. F. T.** 862 (2.5). **Menezes, T. G. C.** 199 (2.4). **Meyer, L. M. N.** 8 (1.3). **Miranda, A. M.** 796 (1.7), 969 (1.7), 3220 (1.7), 3649 (1.7), 6166 (2.5), 5038 (2.5). **Moraes, J. C.** 1155 (2.2). **Nascimento L. M.** 113 (1.8), 328 (1.8). **Noblick, L. R.** 3701 (1.7), 3111 (1.8), 3183 (1.8), 3544 (2.5). **Nolasco, P.** 21 (2.3). **Nunes, T. S.** 216 (2.2). **Occhioni, P.** 698 (1.2). **Oliveira, A. A.** 3142 (2.5), 3216 (2.5). **Oliveira, M.** 2790 (1.7), 3250 (1.7), 3788 (2.4), 1369 (2.5), 1753 (2.5), 2591 (2.5), 3505 (2.5). **Oliveira, R. P.** 532 (2.5). **Paes, G. C. L.** 199 (1.1). **Patore, J. F. B.** 5112 (2.5). **Perdiz, R. O.** 786 (1.6). **Pereira, A. B.** 173 (1.1), 174 (1.1). **Pereira, E.** 118 (1.1), 5357 (1.5), 7906 (2.5), 8395 (2.5). **Pereira, R. S.** 28 (2.3). **Pessoa, L. M.** 23 (1.7).

Pickel, D. B. 2555 (1.7). **Pinheiro, F. C.** 158 (1.1). **Pinheiro, K.** 743 (2.5), 420 (2.5). **Pinheiro, R. S.** 1537 (1.8), 1539 (1.8). **Pinto, G. C. P.** 641 (1.5), 99 (1.7). **Pinto, L. S.** 802 (1.1). **Pirani, J. R.** 2973 (1.1). **Platais, G. H.** 15 (1.1), 4 (1.2). **Plaumann, F.** 437 (1.5). **Popovkin, A. V.** 294 (2.5). **Possette, R. F. S.** 510 (1.5). **Queiroz, L. P.** 1005 (1.8), 1007 (1.8), 12047 (1.8), 12930 (1.8), 1740 (2.5), 5798 (2.5), 5931 (2.5), 5965 (2.5), 10002 (2.5). **Queiroz, R. T.** 375 (1.7), 659 (1.7), 677 (2.2). **Ramos, C. E.** 499 (1.6), 41 (1.8). **Reeves** 3035 (2.1). **Ribas, O. S.** 6845 (1.5). **Rizzon, E.** 57 (1.5). **Rocha, F. O.** 225 (1.6). **Rodal, M. J. N.** 479 (2.5). **Rodrigues, I. A.** 41 (1.1). **Roque, N.** 2479 (2.5). **Rosa, P.** 794 (1.1), 818 (1.1), 253 (1.2). **Sales, M. F.** 763 (1.7), 537 (2.5), 1127 (2.5). **Salino, A.** 3262 (1.8), 3263 (1.8). **Santos, L. L.** 259 (1.7), 244 (2.5). **Santos, M. O.** 36 (1.7), 37 (1.7), 38 (1.7), 39 (1.7), 40 (1.7), 41 (1.7), 42 (1.7), 43 (1.7), 44 (1.7), 45 (1.7), 46 (1.7), 47 (1.7), 48 (1.7), 49 (2.4), 50 (2.4), 51 (2.4), 52 (2.4), 30 (2.5), 31 (2.5), 32 (2.5), 33 (2.5), 34 (2.5), 35 (2.5), 93 (2.5), 94 (2.5), 95 (2,5), 96 (2.5), 97 (2.5), 98 (2.5), 99 (2.5), 100 (2.5), 101 (2.5), 102 (2.5), 103 (2.5). **Santos, T. S.** 423 (2.5). **Santos, V. J.** 421 (2.5). **Santos-Filho, F. S.** 71 (1.7). **Schinini, A.** 8052 (1.5). **Schwacke, P.** 1875 (1.1). **Shepherd, G. J.** 4501 (1.6). **Silva, A. A. B.** 20 (2.2). **Silva, A. G.** 218 (1.8), 275 (1.8), 325 (1.8), 327 (1.8). **Silva, K. A.** 297 (1.7), 387 (1.7). **Silva, L. L.** 1 (1.2). **Silva, M. J.** 393 (1.7), 23 (1.8), 62 (1.8), 24 (2.5). **Silva, P.** 77 (2.5). **Silva, R. A.** 475 (1.7), 657 (1.7), 1431 (1.7), 807 (2.4). **Silva, R. C. C.** 59 (1.1). **Silva, S. I.** 280 (1.7), 422 (1.7), 556 (1.7), 677 (1.7). **Simões, S. S.** 151 (1.8). **Smith, L. B.** 11747 (2.5). **Sobral, M.** 15593 (1.5), 5845 (2.5). **Souza, E. B.** 3068 (1.7), 3532 (2.2). **Souza, J. P.** 10889 (2.2). **Souza, M. A.** 1208 (2.5). **Strang, H. E.** 470 (1.1). **Sucre, D.** 4459 (1.1), 5366 (1.1), 6030 (1.1), 6088 (1.1), 6186 (1.1), 7752 (1.1), 10087 (1.1), 1750 (1.2), 8517 (1.2), 4473 (2.5), 4624 (2.5), 7905 (2.5). **Tessmann, G.** 63 (1.5), 64 (1.5), 78 (1.5). **Thomas, W. W.** 11835 (1.1), 9242 (1.8). **Valadão, R. M.** 465 (1.3), 680 (1.3), 490 (1.6). **Verdi, M.** 7078 (1.8). **Wasum, R. A.** 3773 (1.5). **Weyland-Vieira, M. C.** 1639 (2.5). **Xavier, A. B.** 352 (2.5). **Zardini, E. M.** 40727 (1.5), 42561 (1.5), 49069 (2.5).

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Author Contributions

Mirane de Oliveira Santos: contribution to data collection, data analysis and interpretation, and manuscript preparation;

Wesley Patrício Freire de Sá Cordeiro: contribution to critical revision, adding intelectual content.

Margareth Ferreira de Sales: contribution to manuscript preparation and critical revision.

Juliana Santos Silva: contribution to manuscript preparation and critical revision, adding intelectual content.

Conflicts of interest

The author declare that they have no conflict of interest related to the publication of this manuscript.

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Winged ants (Hymenoptera: Formicidae) presence in twigs on the leaf litter of Atlantic Forest

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Abstract: In the leaf litter, ants have various nesting resources available, such as live or dead trunks, twigs, leaves, fruits and seeds. On the twigs, there are adults and immature individuals, but also the queen and winged. The production of wings requires time and energy from the colony. The objective of this study was to investigate the presence of winged in ant colonies in twigs on the leaf litter. Our prediction is that the richness and abundance of winged in twigs are the greatest in rainy months. We collected all twigs with ants in 552 plots with 16 m^2, totaling 8,832 m^2 of leaf litter, in areas located in the Brazilian Atlantic Domain. We compared the species richness and the number of colonies with and without winged, as well as the number of winged over a year. In total, we collected 1,521 twigs with colonies belonging to 92 species of ants. The rate of twigs with winged was low, about 12%. In colonies with winged, the total number of twigs, species and amount of winged does not differ between the months considered dry and rainy. The majority of winged species are leaf litter dwellers, such as *Linepithema neotropicum*, recorded with the highest amount of winged irrespective of the period. Arboreal species colonized 15% of the twigs and, in 1/3 of these species, winged were recorded as part of the composition of the colony. Although winged represent a small percentage of the colony in twigs, our results indicate that this feature is important for the life cycle of 44% of the species that occupy twigs, considering that winged are fundamental for the dispersion of the colony.

Keywords: *Dead wood, mating, satellite nest, inhabitant of leaf litter, arboreal habitat.*

Colônias de formigas (Hymenoptera: Formicidae) com alados em galhos na serapilheira de Floresta Atlântica

Resumo: Na serapilheira as formigas têm disponíveis diversos recursos de nidificação, como troncos e galhos vivos ou mortos, folhas, frutos e sementes. Nos galhos são encontrados indivíduos adultos e imaturos, mas também rainha e alados. A produção de alados exige tempo e energia por parte da colônia. O objetivo deste estudo foi investigar a presença de alados em colônias de formigas em galhos na serapilheira. Nossa hipótese é que a riqueza e abundância de alados em galhos são maiores nos meses chuvosos. Nós coletamos todos os galhos com formigas em 552 parcelas de 16 m^2, totalizando 8.832 m^2 de serapilheira em áreas localizadas no Domínio Atlântico brasileiro. Comparamos a riqueza de espécies e o número de galhos com e sem alados, bem como o número de alados ao longo de um ano. No total coletamos 1.521 galhos com colônias, pertencentes a 92 espécies de formigas; a taxa de galhos com alados foi baixa, cerca de 12%. Nas colônias com alados, o número total de galhos, espécies e quantidade de alados não diferem entre os meses secos ou chuvosos. A maioria das espécies com alados é habitante da serapilheira, como *Linepithema neotropicum*, registrada com a maior quantidade de alados, independente do período. Espécies arborícolas colonizaram 15% dos galhos e, em 1/3 dessas espécies, alados foram registrados fazendo parte da composição da colônia. Apesar de os alados representarem uma pequena porcentagem da colônia em galhos, nossos resultados indicam que este recurso é importante para o ciclo de vida de 50% das espécies que os ocupam, considerando que alados são fundamentais para a dispersão da colônia.

Palavras-chave: *Madeira morta, acasalamento, ninho satélite, habitantes de serapilheira, habitat arbóreo.*

Introduction

The first cycle of life of an ant colony is complete when there is release of winged, which allows species dispersal (Hölldobler & Wilson 1990). The production of winged requires time and a high energy investment by the colony (Frank 1987). Temperature and rainfall are important stimuli for winged production (Frederickson 2006, Nielsen et al. 2016) and for the synchronized release of different colonies of the same species (Kaspari et al. 2001a, Peeters & Molet 2010).

Rainfall, in addition to influencing winged release (Kaspari et al. 2001b), facilitates soil excavation for nesting after mating (Hölldobler & Wilson 1990). Mating is the beginning of breeding (Nene et al. 2016), and is important for understanding population ecology and species distribution (Dunn et al. 2007, Noordijk et al. 2008). For example, the species *Oecophylla smaragdina* (Fabricius 1775) has a long mating period, and the colony hosts winged at different stages of development that are released gradually (Nielsen et al. 2016).

The foundation of colonies by ants happens from the soil to the highest extracts of the vegetation, such as the canopies of forests. Sites with diverse nesting resources, such as the leaf litter of tropical forests, also containing live or dead trunks and twigs, leaves, fruits and seeds, are the most densely colonized (Hölldobler & Wilson 1990, Delabie et al. 2000). Twigs from tree fragmentation are one of the most commonly used resources in the litter by ant colonies (Gomes et al. 2013), and where we may find between 35-70 species of ants (Carvalho & Vasconcelos 2002, Souza-Campana et al. 2017). In spite of the low durability of the twigs, causing displacement of the colonies (Byrne 1994), winged have been recorded frequently (Fernandes et al. 2012, Souza et al. 2012).

In this work, we investigate the presence of winged in colonies that occupy twigs as nesting sites in the leaf litter of the Brazilian Atlantic Forest. We compare the number of species that produce winged and the number of winged over a year. As the warm and rainy season in the Atlantic Forest are known to be the period of higher ant activity (Nene et al. 2016) and with more favorable environmental conditions for the release of the breeding stock (Santos & Del-Claro 2009), we expect to find such an influence also in species that occupy twigs.

Material and Methods

1. *Study area, collection and identification of ants*

The collection expeditions were carried out in 43 fragments of vegetation at different conservation levels belonging to nine municipalities in the Brazilian Atlantic Domain (Fig. 1). The altitudes are between 600 and 850 m. According to the Köppen classification, the climate of the region is mesothermic with a dry winter (Cwb), with an annual rainfall accumulation of 1,500 mm (Cptec-Inpe 2018). In these municipalities, the rainy season occurs between March and October, and the dry season occurs between April and September (Cptec-Inpe 2018).

The collections were carried out along a linear transect between 2010 and 2015 covering the months considered as dry (April to September) and rainy (October to March) for the region. In each site, we determined 4 x 4 m plots. The distance between plots was 10-50 m, and the number of plots (6-30) was determined in function of the size of the study areas. All twigs (= nests) with ants were collected (range diameter: 2.85 to 123.77 mm) and packed in plastic bags individually, and taken to the laboratory for colony analysis; 552 plots were analyzed, totaling 8,832 m^2 of litter. In the laboratory, we opened the twigs in search for ant colonies. We classified twigs as occupied if they contained ≥10 workers; if fewer than 10 workers were present, twigs were considered occupied if they contained immatures, queens, or winged males (Fernandes et al. 2012).

For each twig, the number of individuals was counted. For identification of species/morphospecies, we used the catalog by Suguituru et al. (2015) and a comparison with the specimens deposited in the reference collection of Formicidae of the Upper Tietê Basin. The winged were identified based on the identification of worker ants. We deposited all the vouchers at the Laboratory of Mirmecology of the University of Mogi das Cruzes.

2. *Data analysis*

The total number of ant species and twigs with winged or wingless, and the number of winged on twigs were compared between the one-year dry and rainy periods using Mann-Whitney test. The significance level adopted was 5%, and the tests were performed using the software BioEstat 5.0 (Ayres et al. 2007).

Results

In 1,521 twigs we found 89 species of ants (Table 1), most of them inhabiting leaf litter. The arboreal ants represent 27 species of the total, 12 of which are truly arboreal (genera *Cephalotes*, *Myrmelachista*, *Procryptocerus* and *Pseudomyrmex*) and 15 possibly arboreal (genera *Camponotus* and *Crematogaster*). From this total of twigs, arboreal ants colonized 235 of them (15.45%) (Table 1).

Few twigs (186 = 12%) have colonies with winged, but with 39 (44%) species of ants. Of these, 12 are vegetation species, among which six were defined as arboreal (three species of *Myrmelachista*, two of *Procryptocerus* and one of *Pseudomyrmex*) and six were classified as possibly arboreal (five species of *Camponotus* and one of *Crematogaster*). The other species are leaf litter inhabitants (Table 1).

The total number of twigs with wingless and winged, the total number of wingless and winged ant species, and the abundance of winged do not differ between both periods of the year (Table 2). Winged in twigs were more frequent between October and January (Fig. 2).

The species with the highest occurrence and abundance are not the same when we analyze descriptively the driest and rainiest months (Fig 3). Winged ants of *Brachymyrmex admotus* Mayr 1887 are more frequent when there is more rain, while *Gnamptogenys striatula* Mayr 1884 occur in the driest months. *Nylanderia* sp.1 and *G. striatula* only showed winged ants in twigs in the driest months (Fig. 3A). Regardless of the period of the year, *Linepithema neotropicum* Wild 2007 is the species with the highest number of winged (Fig. 3B).

Discussion

Our results indicate that the number of colonies with winged is low throughout the year, but the presence of breeders is constant for about half of the species that occupy the twigs. We found that most species occupying twigs also inhabit the litter. Few species are totally arboreal.

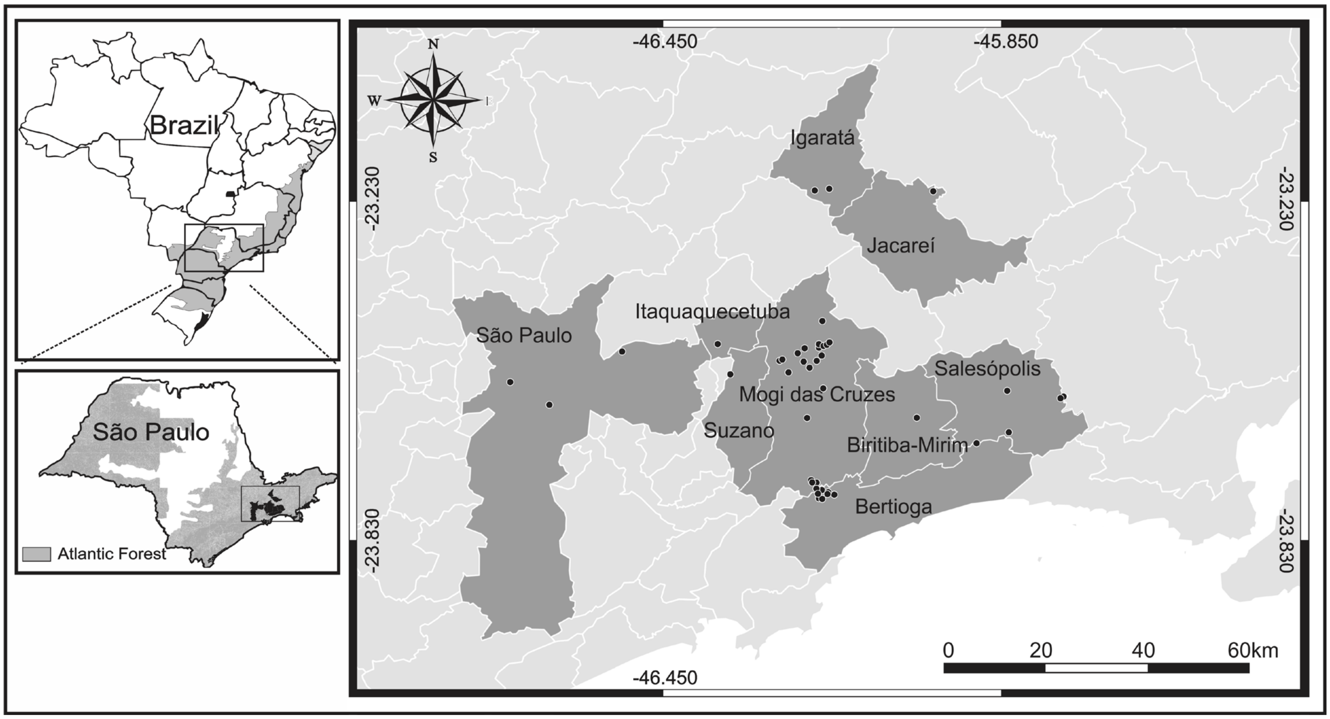

Figure 1. Location of ant collection areas in twigs in the leaf litter in municipalities within the Brazilian Atlantic Domain.

Table 1. List of ant species in twigs on the leaf litter of the Atlantic Forest. The columns describe the number of twigs with and without the presence of winged in two periods of the year.

Species/morphospecies	Dry period		Rainy period	
	Wingless	Winged	Wingless	Winged
Acanthognathus ocellatus Mayr, 1887	3	-	3	1
Acanthognathus rudis Brown & Kempf, 1969	6	1	5	3
Anochetus altisquamis Mayr, 1887	-	-	1	-
Brachymyrmex admotus Mayr, 1887	112	3	21	29
Brachymyrmex heeri Forel, 1874	5	-	1	-
Camponotus alboannulatus Mayr, 1887	11	1	17	3
Camponotus blandus (Smith, 1858)	-	-	3	1
Camponotus crassus Mayr, 1862	5	4	-	-
Camponotus hedwigae Forel, 1912	2	-	2	-
Camponotus novogranadensis Mayr, 1870	3	-	1	-
Camponotus sp.5	9	1	5	1
Camponotus sp.18	-	-	1	-
Camponotus sp.20	1	1	-	-
Cardiocondyla wroughtonii (Forel, 1890)	1	-	-	-
Cephalotes pusillus (Klug, 1824)	2	-	-	-
Crematogaster curvispinosa Mayr, 1862	7	-	2	-
Crematogaster rochai Forel, 1903	3	-	-	-
Crematogaster sp.1	3	-	7	2
Crematogaster sp.7	4	-	-	-
Crematogaster sp.18	8	-	4	-
Crematogaster sp.19	1	-	-	-
Crematogaster sp.20	-	-	2	-
Cyphomyrmex rimosus (Spinola, 1851)	1	1	-	1

Continuation Table 1.

Species/morphospecies	**Dry period**		**Rainy period**	
	Wingless	**Winged**	**Wingless**	**Winged**
Gnamptogenys striatula Mayr, 1884	13	9	24	-
Heteroponera dentinodis (Mayr, 1887)	5	7	6	1
Heteroponera dolo (Roger, 1860)	1	-	2	-
Heteroponera mayri Kempf, 1962	-	-	16	2
Hylomyrma reitteri (Mayr, 1887)	-	-	1	-
Hypoponera sp.4	12	-	9	-
Hypoponera sp.7	-	-	7	-
Hypoponera sp.10	-	-	5	1
Hypoponera sp.11	-	-	12	3
Hypoponera sp.12	7	1	19	5
Linepithema iniquum (Mayr, 1870)	11	-	8	1
Linepithema leucomelas (Emery, 1894)	1	1	-	2
Linepithema neotropicum Wild, 2007	8	4	45	10
Megalomyrmex goeldii Forel, 1912	4	-	-	-
Megalomyrmex iheringi Forel, 1911	1	-	1	-
Megalomyrmex sp.n.	1	-	-	-
Mycetarotes parallelus (Emery, 1906)	-	-	1	-
Myrmelachista catharinae Mayr, 1887	3	-	18	4
Myrmelachista nodigera Mayr, 1887	2	-	1	-
Myrmelachista reticulata Borgmeier, 1928	-	1	-	-
Myrmelachista ruzskyi Forel, 1903	13	-	4	3
Neoponera crenata (Roger, 1861)	2	-	5	3
Nylanderia sp.1	10	6	3	-
Odontomachus affinis Guérin-Méneville, 1844	-	-	1	-
Paratrechina sp.1	1	-	3	-
Pheidole alpinensis Forel, 1912	2	-	3	-
Pheidole flavens Roger, 1863	17	1	33	2
Pheidole sarcina Forel, 1912	68	1	107	10
Pheidole sigillata Wilson, 2003	87	7	34	1
Pheidole sospes Forel, 1908	40	6	48	10
Pheidole triconstricta Forel, 1886	1	-	-	-
Pheidole gr. *tristis* sp.	2	-	18	4
Pheidole sp.18	2	-	-	-
Pheidole sp.19	-	-	5	1
Pheidole sp.23	-	-	3	-
Pheidole sp.37	3	-	-	-
Pheidole sp.39	1	-	-	1
Pheidole sp.43	1	-	30	-
Pheidole sp.44	9	-	-	-
Pheidole sp.51	-	-	4	3
Pheidole sp.52	2	-	3	-
Pheidole sp.53	-	-	1	-
Prionopelta punctulata Mayr, 1866	-	-	2	-
Procryptocerus adlerzi (Mayr, 1887)	5	1	6	-

Continuation Table 1.

Species/morphospecies	Dry period		Rainy period	
	Wingless	Winged	Wingless	Winged
Procryptocerus sp.2	3	-	4	2
Procryptocerus sp.4	4	-	1	-
Pseudomyrmex gracilis (Fabricius, 1804)	5	-	-	-
Pseudomyrmex phyllophilus (Smith, 1858)	18	2	8	1
Pseudomyrmex schuppi (Forel, 1901)	1	-	-	-
Pseudomyrmex gr. *pallidus* sp.	2	-	6	-
Solenopsis saevissima (Smith, 1855)	1	-	-	-
Solenopsis sp.2	46	1	40	8
Solenopsis sp.3	7	3	4	-
Solenopsis sp.4	-	-	5	-
Solenopsis sp.5	1	-	2	2
Solenopsis sp.8	12	1	18	5
Solenopsis sp.9	-	-	-	1
Strumigenys crassicornis Mayr, 1887	3	-	1	-
Strumigenys sp.n	1	-	-	-
Wasmannia affinis Santschi, 1929	7	-	8	3
Wasmannia auropunctata (Roger, 1863)	19	-	-	-
Wasmannia sigmoidea (Mayr, 1884)	12	-	-	-
Species richness by period of the year	67		66	

Table 2. Comparison of species richness, number of twigs and number of winged in twigs with presence or absence of winged in two periods of the year in areas of Atlantic Forest. Median (amplitude) of total twigs, species richness and total number of winged.

Colony		Dry period		Rainy period		Test	*p*
		Total	Median (amplitude)	Total	Median (amplitude)		
	Twig	667	104 (9-230)	668	84 (41-188)	U = 0	1
	Species	66	17 (3-20)	62	8 (4-18)	U = 0.6405	0.5218
	Twig	64	5 (2-42)	122	21.5 (5-32)	U = 1.6013	0.1093
	Species	23	3.5 (2-16)	34	9 (5-12)	U = 1.7614	0.0782
	Abundance of winged ants	750	136 (8-240)	1,249	217 (31-374)	U = 1.1209	0.2623

In addition, we did not detect the influence of dry or rainy months on the presence of winged in twigs, although the release of winged is related to the wetter season since rain is considered an important stimulus (Torres et al. 2001, Santos & Del-Claro 2009).

The production of winged is influenced by factors such as size (Frederickson 2006) and availability (Fiala et al. 2017) of the resource occupied by ants. For some species, such as *C. castaneus* (Latreille, 1802), the production of winged is seasonal (Nascimento et al. 2001, Dunn et al. 2007). However, for others, such as *Azteca instabilis* (Smith, 1862), the production of winged occurs independently from the season (Kaspari et al. 2001b), resembling what we detected in this study. The fact that there is no characteristic period for winged production may indicate a strategy to avoid competition for colonization sites. Arboreal species such as *C. captiosa* (Forel, 1911) use this strategy and produce winged throughout the year (Fiala et al. 2017). This suggests that 32% of the species of our work, which are associated with arboreal habitat and were recorded with winged, may also adopt this type of reproductive behavior.

The twig is a resource of low durability (Byrne 1994), which does not match the time for production of winged individuals, which requires colony maturity (Hölldobler & Wilson 1990). Thus, when it comes to arboreal species, the twig of the tree may contain winged that, when falling in the leaf litter, release the breeders. In this case, the stay on the twig should be only for maturing and dispersal of winged. Nakano et al. (2012) discuss this possibility for species of *Myrmelachista*, which is an exclusively arboreal genus. In the production and dispersion of breeders there is great energy expenditure (Frank 1987) and the arboreal environment is poor in certain components (example: nitrogen) (Wilson

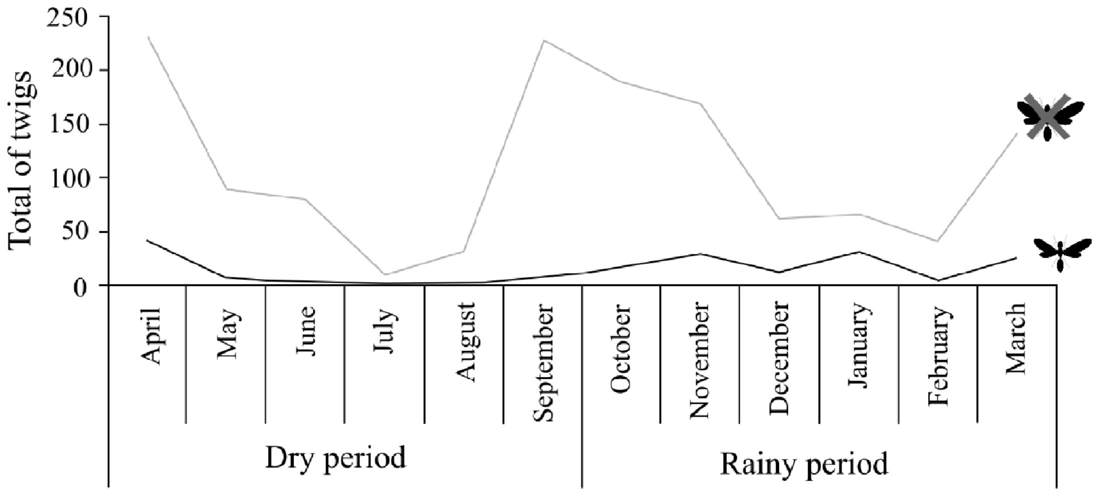

Figure 2. Number of twigs with colonies of ants with and without wings in the leaf litter of Atlantic Forest throughout the year.

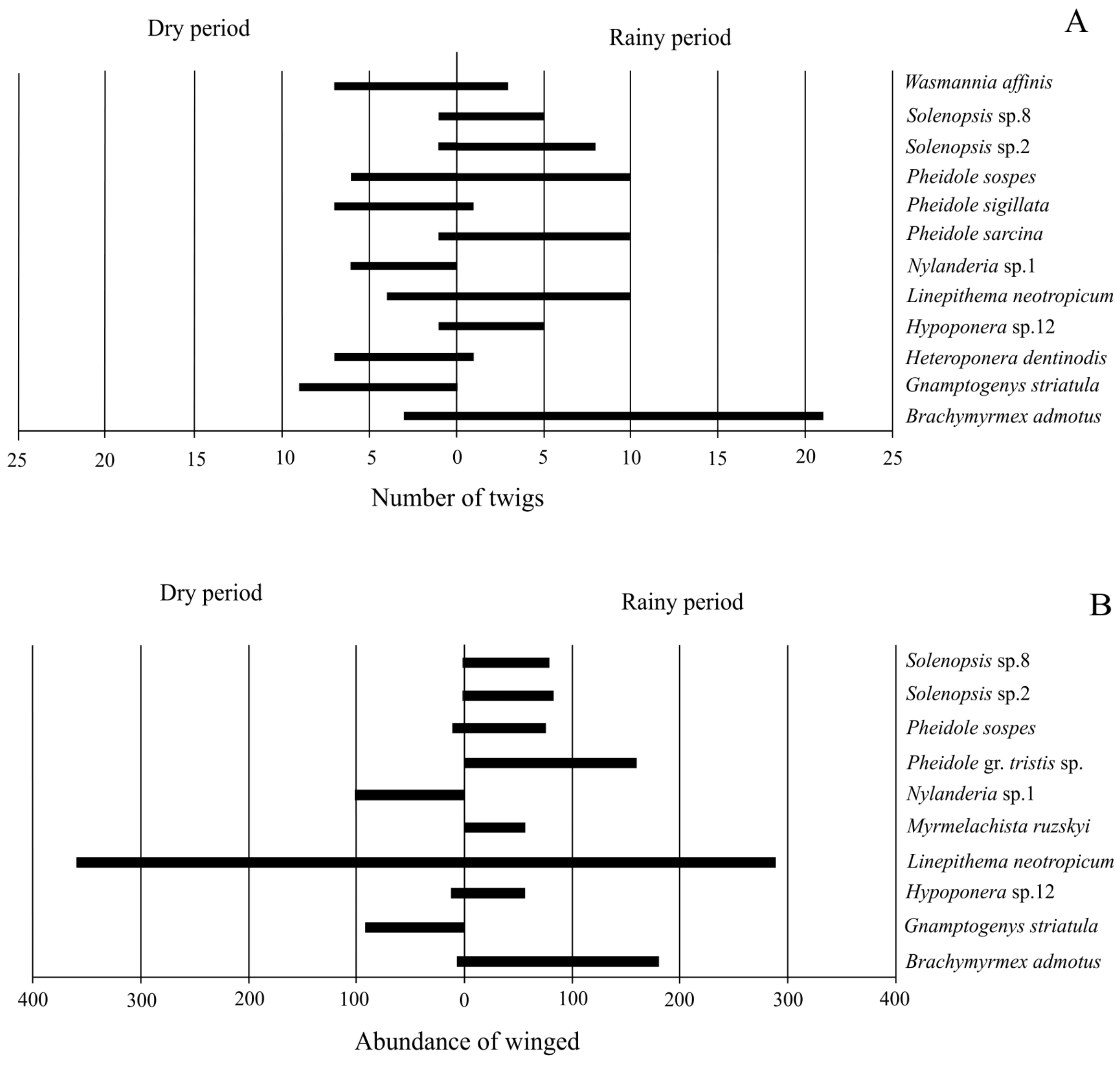

Figure 3. Species of ants in a greater number of twigs with winged ants (A) and with greater abundance of winged ants (B) according to dry and rainy periods.

& Hölldobler 2005) and drier when compared to the leaf litter (Davidson & Patrell-Kim 1996, Yanoviak & Kaspari 2000). In this case, we suggest that some arboreal species are using biotic and abiotic conditions provided by the leaf litter. The ecological success of arboreal ants is a reflection of the adaptation of species to the arboreal environment (Yanoviak & Kaspari 2000), but also, possibly, because they are able to use the resources in the leaf litter during the maturing and dispersal phase of winged ants. However, for most species that colonize twig, the permanence should be comparatively longer, allowing not only the dispersion, but also the production of breeders.

Ants inhabit of the leaf litter that occupy twig produce winged continuously throughout the year, indicating that the resource is important to the life cycle of litter dwellers and, especially, to arboreal species. In view of the continuous presence of winged on a resource that is classified as ephemeral, we suggest that further studies be carried out studying the biology of species that occupy twigs on the leaf litter. This will allow the conservation of the diversity of this fauna on the leaf litter.

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Author Contributions

Tae Tanaami Fernandes: Contribution to data collection; contribution to data analysis and interpretation; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

Rogério R. Silva: Contribution to data analysis and interpretation; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

Débora Rodrigues de Souza-Campana: Substantial contribution in the concept and design of the study, contribution to data analysis and interpretation; contribution to manuscript preparation.

Otávio Guilherme Morais da Silva: contribution to data collection, contribution to data analysis and interpretation, contribution to manuscript preparation.

Maria Santina de Castro Morini: Substantial contribution in the concept and design of the study; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Inventory

Specimens inventory of Tabanidae (Diptera) of Entomological Collection of National Museum of Natural History - Universidade Federal do Rio de Janeiro

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Abstract: A checklist of tabanids of the Entomological Collection of National Museum of Natural History - Universidade Federal do Rio de Janeiro is provide. A total of 5,325 specimens was examined of which 2,916 were found identified, belonging to 341 species, 42 genera e four varieties, collected from all continents since 1902. The currently taxa names were provided when possible, also currently localities of collections.

Keywords: *Checklist, collection inventory, distribution, horse flies, catalog.*

Inventário dos espécimes de Tabanidae (Diptera) da Coleção Entomológica do Museu de História Natural do Rio de Janeiro - Universidade Federal do Rio de Janeiro

Resumo: Uma lista dos tabânidas da Coleção Entomológica do Museu Nacional de História Natural - Universidade Federal do Rio de Janeiro é fornecida. Um total de 5.325 espécimes foi examinado, dos quais 2.916 se encontraram identificados, pertencentes a 341 espécies, 42 gêneros e quatro variedades, coletados em todos os continentes desde 1902. Os nomes atuais dos taxa foram fornecidos quando possível, assim como locais de coletas.

Palavras-chave: *Lista, inventário de coleção, distribuição, mutucas, catálogo.*

Introduction

Horseflies is an important group of hematophagous flies, gathering more than 4,400 species world wide spread (Pape et al. 2011). Tabanids can transmit several pathogenic agents, such as virus, bacterias, protozoans and helminths (Foil, 1989). The studies on this group point inventories, seasonality and diseases transmissions; but in many regions the data available refer only checklists. Entomological collections are important sources of knowledge, furnishing data about geographical distribution and voulcher specimens. Among Brazilian collections, the tabanids collection of Museu Nacional de História Natural do Rio de Janeiro (MNHN-RJ) is considered of great importance for the study of tabanofauna of neotropical region, also as those of Instituto Nacional de Pesquisas da Amazônia (INPA-Amazonas), Museu Paraense Emilio Goeldi (MPEG-Pará), Universidade de São Paulo (USP-São Paulo) and Instituto Oswaldo Cruz (IOC-Rio de Janeiro) (Fairchild 1961a, 1961b; Henriques 1997; Henriques & Gorayeb 1993).The collection was initiated in early last century, and there is no list of species published. Specimens were acquired by donations or acquisitions with Paris Museum, Empresa Brasileira de Pesquisa Agropecuária, Serviço de Febre Amarela of Ministério da Educação e Saúde, Adolpho Lutz Collection of Instituto Oswaldo Cruz, and from collections of C. Seabra, C.B. Philips, C.D. Miller, E.L. Pechuman, E. Séguy, F.M. Oliveira, G.H. Hammond, H.A. Hennigan, H.J. Teskey, H.S. Lopes, J.E.P. Trudel, J.F. McAlpine, J.R. Vockeroth, J. Surcouf, K. Lenko, R.R. Guimarães, S.J. Oliveira, W.R. Coyles and others. This study is part of a project that aims to update the knowledge of tabanofauna of Atlantic Forest Biome. This paper list the species of tabanids of collection of National Museum – Universidade Federal do Rio de Janeiro, and emphasize the Atlantic Forest Biome species. The entomological collection of Museu Nacional de História Natural of UFRJ was burned on 2 September 2018 and the collection of tabanids was entirely lost.

Material and Methods

The specimens of tabanids of MNHN-RJ collection were examined between May and September 2017. The list of species is presented according to classification adopted by Coscarón & Papavero (2009), offering the number of specimens, sex, locality and date of collection, presented by subfamilies, tribes, genera and species in alphabetical order.

Geographical records were ordinated in north to south, and west to east for countries and states. All specimens were counted, and data from labels of identified species were noted: species name, place and date of collection, name of collector and identifier are offered, when available. Other data regarding synonymy and aspects of methods and site of collections are also presented, when available. Geographical data were update, when it was possible, providing currently country, department, state, municipality. Synonymous taxa were update according Moucha (1976), Chainey & Oldroyd (1980), Daniels (1989), Stone, (1975), Burger (1995) and Coscarón & Papavero (2009). The data are presented as following, modified from proposal of Ribeiro et al. (2007): name of species, country of collection, quantity and genre of specimens and date of collection (always furnished in the first label). The labels of each specimen are numbered in parentheses; a vertical dash separate information in different lines of the labels; original data on the labels are in quotes; additional data are included in brackets; semicolon separate information about each specimen or group of specimens; and a dot separates the countries where specimens were collected. Atlantic Forest Biome species are marked with acronym "ATLFO", after presenting data. The list of subfamilies, tribes, genera, subgenera and species is presented in alphabetic order.

Results

The collection includes specimens collected since 1902. A total of 5,325 tabanid specimens were examined of which 2,916 specimens are identified in 42 genera, 351 species and four varieties. The collection comprises 28,3% (42/156) of genera and 7,9% (351/4406) of species of the three subfamilies and ten tribes of family Tabanidae: Chrysopsinae (Bouvieromyini, Chrysopsini, Rhinomyzini), Pangoniinae (Pangoniini, Philolichini, Scepsini, Scionini), and Tabaninae (Diachlorini, Haematopotini, Tabanini). There are no representatives of Mycteromyiini (Pangoniinae). The specimens are stored in 15 drawers in entomological two cabinets of the Entomological Collection of National Museum of Natural History of Universidade Federal do Rio de Janeiro. 2,409 specimens belonging to 12 genera are not identified, from which 996 specimens belong to *Tabanus lineola* complex, 556 to genus *Stypommisa*, 245 to genus *Fidena*, 160 to genus *Pityocera,* and 452 to several other genera (*Catachlorops*, *Chlorotabanus*, *Chrysops*, *Dasybasis*, *Diachlorus*, *Dichelacera*, *Esenbeckia*, *Stenotabanus*); 192 specimens lack determination.

The collection gathers specimens from five continents. There are 159 species in 26 genera from Neotropical region, from which 72 occur on Atlantic Forest biome, marked with acronym "ATLFO". 65 species of 6 genera are originated from Neartic region; Paleartic region is represented by 10 genera and 64 species; 8 genera and 40 species from Afrotropical region; 3 genera and 10 species from Oriental region; and 3 genera and 4 species from Australian region (Fig. 1). Brazilian specimens were mainly collected in northern, eastern and southeastern regions, mainly in states of Amapá, Amazonas, Pará, Mato Grosso, Goiás, Minas Gerais, Espírito Santo, São Paulo, Paraná and Santa Catarina.

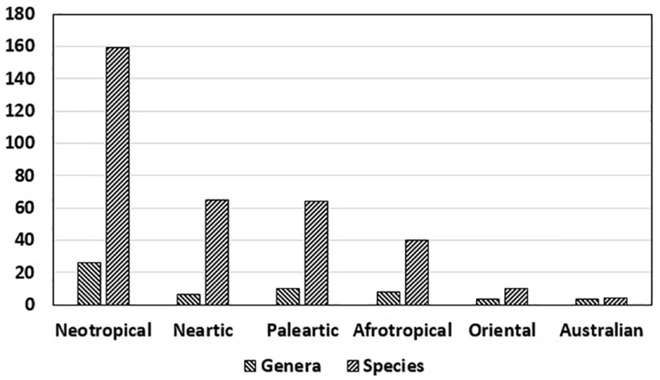

Figure 1. Number of genera and species of tabanids and ecological regions of the word represented in Entomological Collection of National Museum of Natural History – Universidade Federal do Rio de Janeiro, Brazil.

General collection

Family Tabanidae Latreille, 1822

Subfamily Chrysopsinae Blanchard, 1840

Tribus Bouvieromyiini Seguy, 1949

Genus *Bouvierella* Surcouf, 1909 = Subgenus *Triclida* Enderlein, 1923

Bouvierella variegata Walker = *Aegophagamyia (Triclida) variegata* Surcouf, 1908.

Tribe Chrysopsini Blanchard, 1840

Genus *Chrysops* Meigen, 1803

Chrsysops aestuans van der Wulp, 1867 – Canada: 1 ♀ (1) 22-VI-1958 "Manitoba │ 5 min. SW Shilo │ Floodplain Community │ nr. Tamarack Bog"; 1 ♀ (1) "15-VI-1965 Ontario │ Long Point" (2) "R. Idema".

Chrysops aberrans Philip, 1941 – Canada: 1 ♀ (1) "12-VIII-1943 Ontario │ Marmora" (2) "G.H. Hammond"; 1 ♀ (1) "14-VI-1967 Ontario │ Wagensville[?]" (2) "H.J. Teskey".

Chrysops algerus Macquart, 1834 = *Chrysops algirus* Meigen, 1830.

Chrysops algirus Meigen, 1830 as *Chrysops algerus* Macquart, 1834 – Algeria: 1 ♀ (1) "V/VI-1912 Algerie │ Rocher Blanc [Le Corso] │ J. Surcouf" (2) "2953"; 1 ♀ (1) "V/VI-1911 Algerie │ Rouiba │ J. Surcouf" (2) "2954".

Chrysops asbestos Philip, 1950 – Canada: 1 ♀ (1) "13-VI-1973 British Columbia │ Princenton" (2) "H.J. Teskey".

Chrysops ater Macquart, 1850 – Canada: 1 ♀ (1) "22-VI-1956 Alberta │ Oldman River Lethbridge" (2) "E.E. Sterns"; 1 ♀ (1) "21-VI-1943 Ontario │ Marmora" (2) "G.H. Hammond"; 1 ♀ (1) "4-VI-1949 Nfld. [Newfoundland and Labrador], Gander" (2) "H.A. Hennigan".

Chrysops caecutiens (Linnaeus, 1761) – France: 1 ♀ (1) "VII-1907 Cote du Nord │ Lamballe" (2) "2774" (3) "J. Surcouf"; 1 ♀ (1) "21-VIII-1939 Marans │ M. et L." (2) "2773". Italy: 1 ♀ (1) "28-V-1933 Lombardia │ Tubigo, 140 m │ F. Ticono, L. Ceresa" (2) "EMBRAPA" (3) "*C. caecutiens* L. │ Det H.S. Lopes".

Chrysops callida = *Chrysops callidus* Osten Sacken, 1875.

Chrysops callidus Osten Sacken, 1875 as *Chrysops callida* – Canada: 1 ♀ (1) “21-VI-1959 Ontario │ Galt” (2) “H.J. Teskey”; 1 ♀ (1) “4-VIII-1962 Ontario │ Hamilton” (2) “D.M. Wood”. USA: 1 ♀ (1) “12-VIII-1939 N. Y. [New York] │ Olcott” (2) “E.L. Pechuman”.

Chrysops calvus Pechuman & Teskey, 1967 – Canada: 2 ♀♀ both with labels (1) “21-VI-1955 Quebec │ Manie Depot Baie-Comeau” (2) “J.E.P. Trudel”.

Chrysops carbonaria = *Chrysops carbonarius* Walker, 1848.

Chrysops carbonarius Walker, 1848 as *Chrysops carbonaria* – Canada: 1 ♀ (1) “20-VI-1954 Quebec │ Harrington LK [Lake] [Lac Mosseau] │ Gatineau Pk. [Park]” (2) “W.R. Coyles”.

Chrysops cinticornis Walker 1848 – Canada: 1 ♀ (1) “6-VI-1941 Ontario │ Marmora” (2) “G.H. Hammond”; 1 ♀ (1) “25-V-1943 Ontario │ Marmora” (2) “G.H. Hammond”.

Chrysops cordigera Bigot = *Hematopota cordigera* Bigot, 1891.

Chrysops crucians peruviana = *Chrysops peruviana* Burger, 1999.

Chrysops crucians Wiedemann, 1828 – Brazil: 1 ♀ [no date] (1) “Rio de Janeiro │ Itatiaia │ J. F. Zilkán” (2) “nº 1103 │ DIPTERA │ Inst. Oswaldo Cruz”; 1 ♀ (1) “14-X-1957”, 1 ♀ “28-X-1957”, 1 ♀ “8-XI-1957”, 1 ♀ “30-XI-1957”, 1 ♀ “21-XII-1957”, 1 ♀ “30-XII-1957”, 1 ♀ “12-II-1958”, all specimens with more three labels: (2) “São Paulo │ Barueri” (3) “Coleção Campos Seabra” (4) “K. Lenko”.

Chrysops cuclux Whitney, 1879 – Canada: 1 ♀ (1) “19-VI-1953 Ontario │ Maynooth” (2) “J.F. Mc Alpine”; 1 ♀ (1) “20-VI-1954 Quebec │ Harrington LK [Lake] [Lac Mosseau │ Gatineau Pk. [Park]” (2) “W.R. Coyles”. USA: 1 ♀ (1) “18/29-VI-1939 (2) “New York │ Constantia” (3) “E.L. Pechuman”.

Chrysops dawsoni Philip, 1959 – Canada: 1 ♀ (1) “2-VI-1955 Alta. [Alberta] [Fort] │ McMurray” (2) “W.J. Brown”. USA: 1 ♀ (1) “26-VI-1950 Man. [(Manitoba]) Guillam [Gillam]” (2) “J.F. Mc Alpine”.

Chrysops discalis Williston, 1880 – Canada: 1 ♀ (1) “10-VI-1959 B.C. [British Columbia] Oliver │ Spectacle L. [Lake]” (2) “L.A. Kelton”; 1 ♀ (1) “16-VI-1955 Sask. [Saskatchewan] │ Willow Bunch │ C.D. Miller”.

Chrysops dispar Fabricius, 1798 – India: 1 ♀ (1) “1911 Inde Meridionale │ Trichinopoly │ P. Caius” (2) “2794”; 1 ♀ [no date] (1) “Aman Huê │ Bauchelgie” [Huệ Châu, Guangdong] (2) “2800”.

Chrysops excitans Walker, 1850 – Canada: 1 ♀ (1) “29-VI-1938 Sask. [Saskatchewan] │ Christopher Lake” (2) “A.R. Brooks”; 1 ♀ (1) “5-VI-1948 “Labr. [Labrador] │ Goose Bay” [Happy Valley-Goose Bay] (2) “H.C. Friesen”. USA: 1 ♀ (1) “14-VI-1925 Minnesota │ Anoka Co.” (2) “C.B. Philips │ Det. C.B. Philips”; 1 ♀ (1) “28-VI-1927 “Aspen Grove [Utah │ P.N. Vromm” (2) “2776”.

Chrysops fixissimus Walker, 1856 – Singapore: 2 ♀♀ with labels (1) “8-IV-1908 Croisiére de “Nirvana” │ E. Cordier │ Coll C. de Blarn” (2) “Museum Paris │ Ctesse. de Blarn │ 1909” and (3) “2755” and (3) “1756” each one.

Chrysops flavida = *Chrysops flavidus* Osten Sacken, 1821.

Chrysops flavidus Osten Sacken, 1821 as *Chrysops flavida* – USA: 1 ♀ (1) “11-VI-1941 Alabama │ Pryor Springs │ Decatour” [Deacatur] (2) “J.N. Belkin │ Det J.N. Belkin”.

Chrysops formosus Kröber, 1926 – Brazil: 1 ♀ (1) “18-III-1990 Pará │ Belém │ Capoeirão”.

Chrysops frigidus Osten Sacken, 1875 – Canada: 1 ♀ (1) “2-VI-1925 Ont. [Ontario] Low Bush │ Lake Abitibi” (2) “N.K. Bigelow”; 1 ♀ (1) “10-VI-1956 Ont. [Ontario] Maynooth” (2) “J.F. Mc Alpine”.

Chrysops fuliginosa = *Chrysops fuliginosus* Wiedemann, 1821.

Chrysops fuliginosus Wiedemann, 1821 as *Chrysops fuliginosa* – USA: 1 ♀ (1) “13-VI-1940 New Jersey │ Tuckerton” (2) “J.N. Bekin”.

Chrysops furcata = *Chrysops furcatus* Walker, 1848.

Chrysops furcatus Walker, 1848 as *Chrysops furcata* – Canada: 1 ♀ (1) “13-VI-1955 Cartwright Lab.” [Newfoundland and Labrador] (2) “E.F. Cashman”. USA: 1 ♀ (1) “28-VI-1963 Colo. [Colorado] Timber Ck. [Creek] │ Camp Rock M. Nat. Pk. [Rocky Mountain National Park]” (2) “G.C. & D.M. Wood”.

Chrysops geminatus Wiedemann, 1828 – USA: 1 ♀ (1) “25-VI-1936 New York │ Lockport” (2) “E.L. Pechuman”.

Chrysops incisus Macquart, 1846 – Brazil: 1 ♀ (1) “XI-1973 Rondonia │ Vilhena”.

Chrysops india = *Chrysops indus* Osten Sacken, 1875.

Chrysops indus Osten Sacken, 1875 – Canada: 1 ♀ (1) “17-VI-1924 Que. (Quebec) Covey Hill” (2) “C.H. Curran”; 1 ♀ (1) “1-VI-1932 Ont. [Ontario], Simoes” (2) “T.N. Freeman”. USA: as *Chrysops india* 1 ♀ (1) 13-VI-1939 New York │ Two Bridges, Orleans Co. [Community]” (2) “E.L. Pechuman”.

Chrysops italicus Meigen, 1804 as *Chrysops marmoratus* Rossi – [South Europe, North Africa and West Asia]: 2 ♀♀ [no date] with labels (1) “1909 “Museum Paris │ Coll. G.A. Poujade” and (2) “2839” and (2) “2840” each one.

Chrysops japonicus Wiedemann, 1828 – Japan: 1 ♀ (1) “27-IV-1909 Japon │ Tokyo │ Edme Galloios” (2) “2760” [with no head and thorax].

Chrysops laetus Fabricius, 1805 – Brazil: 1 ♀ (1) “26-XI-1981 Amapá │ Matapi │ BR 156, Km 14”; 4 ♀♀: (1) “21-VI-1929”, “4-XI-1946”, “9-VI-1948”, “27-II-1948” Santa Catarina │ Bom Retiro” [?]; as *Chrysops laeta* Fabr. 2 ♀♀, each specimen with three labels: (1) “2-VI-1958 Minas Gerais │ Gov. [Governador] Valadares” (2) “Coleção Campos Seabra” and (3) “K. Lemko”; 2 ♀♀: each specien with labels (1) “13-IV-1957” and (1) “12-IV-1958 and “São Paulo │ Barueri” (2) “Coleção Campos Seabra” (3) “K. Lenko”.

Chrysops lateralis Wiedemann, 1828 – Canada: 1 ♀ (1) “8-VI-1930 Que. [Quebec] Knowlton” (2) “L.J. Mine”; 1 ♀ (1) “4-VI-1953 Que. [Quebec] Cap Rouge” (2) “Lambert”.

Chrysops longicornis Macquart, 1838 as *Chrysozona longicornis* Macquart – Gabon: 2 ♀♀ [no date] each specimen with two labels (1) “1912 Museum Paris │ Ogooué, Lambaréne │ R. Ellenberger” and (2) “2848” and (2) “2849” each one. Republic of Congo: as *Hyppocentrum trimaculatus* Bigot 1892 – 1 ♀ (1) “3-VIII-1917 Bio-Berj D’Ifockenroth │ Museum Paris │ Coll. Surcouf” *Hyppocentrum 3-maculatum* Rusti” (2) *strigipenne* Karl [in error] (3) *Hyppocentrum trimaculata* │Newstead, 1907” (4) “*strigipenne* (Karsch, 1889)”; 1 ♀ (1) “20-V-1907 Guiné Fr.” (2) “Museum Paris │ Coll. Surcouf 1919” (3) “3005”.

Chrysops macquarti Philip, 1961 – Canada: 1 ♀ (1) “9-VI-1958 Ont. [Ontario] Ertin │ Kahinikuauminan” (2) “H.J. Teskey”; 1 ♀ (1) “4-VIII-1962 Ont. [Ontario] Valens │ Wentworth Co [Community]” (2) “Taylor & Wood”.

Chrysops mactans Austen, 1908 = *Haematopota mactans* Austen 1908.

Chrysops marmoratus Rossi = *Chrysops italicus* Meigen, 1804.

Chrysops mauritanicus Costa, 1893 – Argelia: 2 ♀♀ both specimens with label (1) “16-VI-1913 J. Surcouf │ *Chrysops mauritanicus* Costa │ Krober det. 1921” and labels (2) “2764” and (2) “2765” each one.

Chrysops mitis Osten Sacken, 1875 – Canada: 1 ♀ (1) “27-VI-1955 Sask. [Saskatchewan] Assiniboia” (2) “Vockeroth”; 1 ♀ (1) “17-VI-1934 Ont. [Ontario] Moosone” (2) “G.S. Walley”; 1 ♀ (1) “27-V-1959

Ont. [Ontario] Port Severn | 3 mi N” (2) “Black Spruce Bog” (3) “J.G. Chillcott”.

Chrysops montanus Osten Sacken, 1875 – Canada: 1 ♀ (1) “26-VI-1944 Ont. [Ontario] | Marmora” (2) “G.H. Hammond”; 1 ♀ (1) “15-VI-1965 Ont. [Ontario] | Lin Point” (2) “R. Idema”.

Chrysops niger Macquart, 1828 as *Chrysops nigra* – Canada: 1 ♀ (1) “26-VI-1960 Ont. [Ontario] | One Sided Lake” (2) “Kelton & Whitney”; 1 ♀ (1) “26-VI-1954 Que. [Quebec] | Harrington Lk. [Lake] [Lac Mosseau] | Gatineau Pk. [Park]” (2) “W.R. Coyles”. USA: 1 ♀ (1) “6-VI-1934 (1) “New York | Mud Pond | McLean Res”.

Chrysops nigra = *Chrysops niger* Macquart, 1828.

Chrysops nigripes Zetterstedt, 1838 – Canada: 1 ♀ (1) “25-VII-1948 (Y.T. [Yukon Territory | Dry Creek” (2) “M.T. Hughes”; 1 ♀ (1) “12-VI-1960 Y.T. [Yukon Territory] | Swim Lakes | 133°62′13″ [?], 3200´” (2) “J.E.H. Martin”.

Chrysops noctifer Osten Sacken, 1877 as *Chrysops noctifera* – Canada: 1 ♀ (1) “16-VI-1948 B. C. [British Columbia] | Cultus Lake” (2) “H.R. Foxlee”; 1 ♀ (1) “2-VI-1955 13 mi; from Banff | Banff-Jasper Hw. | 4500” (2) “H.R. Coyles.

Chrysops noctifera = *Chrysops noctifer* Osten Sacken, 1877.

Chrysops pellucidus Fabricius, 1905 – India: 2 ♀♀ both specimens with label (1) “1911 Inde Meridionale | Trichinopoly | F. Caius” and labels (2) “2753” and (2) “2754” each one.

Chrysops peruviana Burger, 1999 as *Chrysops crucians peruviana* [probably misidentified] – Brazil: 1 ♀ (1) “30-XI-1957 (1) “São Paulo | Barueri” (2) “Coleção Campos Seabra” (2) “K. Lenko”.

Chrysops relictus Meigen, 1820 – [Europe, West and Central Asia]: 1 ♂ [no date] (1) “Frank Od. M.P. Riedel” (2) “*relictus* Mg Macho” (3) “EMBRAPA” [with no head]; 2 ♀♀ [no data and no head].

Chrysops rufipes Meigen, 1820 – France: 1 ♀ (1) “9-VI-1914 Meudon | Villebon” (2) “Museum Paris | Coll. E. Séguy” (2) “*Chrysops rufipes* Meig | E. Séguy det 1919” (3) “2841”; 1 ♀ (1) “9-VI-1914 Meudon | Villebon” (2) “Museum Paris | Coll. E. Séguy | *rufipes* Meig” (3) “2842”.

Chrysops sackeni Hine, 1903 – Canada: 1 ♀ (1) “6-VI-1941 Ont. [Ontario] | Marmora” (2) “G.H. Hammond”.

Chrysops shermani Hine, 1907 – Canada: 1 ♀ (1) “9-II-1965 Ont. [Ontario] | Maynooth” (2) “F.F. Mc Alpine”; 1 ♀ (1) “29-VI-1962 Que. [Quebec], Beechgrove [Beech Grove] | 45°90′, 76°8′” (2) “J.R. Vockeroth”.

Chrysops silacea Aust. = *Chrysops silaceus* Austen, 1907.

Chrysops silaceus Austen, 1907 as *Chrysops silacea* Aust. – Ethiopia: 2 ♀♀ both specimens with label (1) “VI-1907 “Massiepa” [Massie, PA [?] and labels (2) “2850” and (2) “2851” each one.

Chrysops sinensis Walker, 1857 – China: 1 ♀ (1) “24-V-1917 Zika-Wei” [Shangai] (2) “2769”; 1 ♀ (1) “14-V-1919 Zika-Wei” (2) “1770”.

Chrysops sordidus Osten Sacken, 1875 – Canada: 1 ♀ (1) “22-VI-1925 Ont. [Ontario] | Low Bush | Lake Abitibi” (2) “N.K. Bigelow”; 1 ♀ (1) “1-VIII-1955 Cartwright Lab. [Newfoundland and Labrador]” (2) “E.E. Sterns”.

Chrysops sp. (*aff. varians*) – Brazil: 8 ♀♀ all specimens with label (1) “IV-1972 “Pernambuco | Caruaru”; 2 ♀♀ (1) “I-1933”, 1 ♀ (1) “XII-1936”, both with “Goiás | Campinas” on label 1, and (2) “EMBRAPA”; 3 ♀♀ (1) “I-1936 with “Goiás | Jataí” (2) “EMBRAPA”; 1 ♀ (1) “XI-1971”, 2 ♀♀ (1) “XI-1972” all with “Goiás | Jataí” on label 1; 1 ♀ (1) “XII-1929 Mato Grosso do Sul | Faz. Murtinho” (2) “EMBRAPA”; 1 ♀ (1) “02-VIII-1960 Minas Gerais | Conceição da Aparecida | Fazenda São José”; 18 ♀♀ “XI-1970 Minas Gerais | Pedra Azul”, 17 ♀ “X-1971 Minas Gerais | Pedra Azul”, 6 ♀♀ “IX-1972 Minas Gerais | Pedra Azul”, 3 ♀♀ “V-1972 Minas Gerais | Pedra Azul”, 53 ♀ “XI-1972 Minas Gerais | Pedra Azul”, 19 ♀♀ “XI-1972 Minas Gerais | Pedra Azul” and (2) “Nº 11/525” each one; 5 ♀♀ [no date] with labels (1) “Minas Gerais | Jaguari” (2) “Nº 11⁄538” each one; 2 ♀♀ (1) “2-VI-1970 Espírito Santo | Alto Jacu”; 1 ♂ (1) “I-1935”, 1 ♀ (1) “XII-1940” Angra dos Reis | Japuhiba” (2) “EMBRAPA” each one; 1 ♀ [no date] (1) “Angra dos Reis | Jussaral” (2) “EMBRAPA”; 1 ♀ (1) “X-1931” [no procedence] EMBRAPA”; 1 ♀ (1) “4-VI-1932 Rio de Janeiro | Rezende” (2) “EMBRAPA”; 1 ♀ (1) “3-XII-1928 Rio de Janeiro | Itatiaia, 700 m” (2) “EMPRAPA”; 1 ♀ (1) “25-XII-1942 Rio de Janeiro | Itatiaia” (2) “EMBRAPA”; 1 ♀ (1) “11-III-1928 Rio de Janeiro | Itaiaia, 400 m” (2) “EMBRAPA”; 1 ♀ (1) “10-VI-1933 Rio de Janeiro | Itatiaia | Estação Biológica, 700 m” (2) “EMBRAPA”; 1 ♀ (1) “I-1930 Rio de Janeiro | [Petrópolis[?], R[io] Fagundes” (2) “EMBRAPA”; 2 ♀♀ (1) “IX-1934 Rio de Janeiro | Rio de Janeiro”; 1 ♂ (1) 1946 Rio de Janeiro | Rio de Janeiro | Deodoro” (2) “EMBRAPA”; 2 ♀♀ [no date] (1) “Rio de Janeiro | Rio de Janeiro” (2) “EMBRAPA”; 1 ♀ (1) “X-1942 Rio de Janeiro [Seropédica] | Km 47, Rio-São Paulo” (2) “EMBRAPA”; 1 ♀ (1) “23-II-1920 Rio de Janeiro | Teresópolis | Vargem de Teresópolis”; 1 ♀ [no date] (1) “Rio de Janeiro | Teresópolis” (2) “Nº 11⁄541”; 1 ♀ (1) “I-1940 Rio de Janeiro | Vassouras”; 1 ♀ [no date] (1) “Rio de Janeiro | Rio de Janeiro” (2) “EMBRAPA”; 1 ♀ (1) “4-IX-1917 São Paulo (São Paulo | (São Paulo), Parque Jabaquara” (2) “Nº 11⁄536”; 1 ♀ (1) “30-X-1916 São Paulo | Santos | Bosque de Santos” (2) “Nº 11/523”; 1 ♀ (1) “21-X-1934 São Paulo | São Paulo | Parque do Estado” (2) “EMBRAPA”; 1 ♀ (1) “XII-1934 São Paulo | São José dos Campos” (2) “EMBRAPA”; 1 ♀ (1) “II-1930 São Paulo | Rio Claro”; 5 ♀♀ all specimens with label (1) “5-III-1925 Paraná | Rio Negro” and labels (2) “Nº 11/525”, (2) “Nº11/526”, (2) “Nº11/529”, (2) “Nº11/530”, (2) “Nº11/532” each one; 2 ♀♀ (1) “III-1971 Santa Catarina | Curitibanos”, each one; 1 ♀ (1) “8-X-1942 (1) “EMBRAPA”; 2 ♀♀ 28-XI-1932 [no other data]; 1 ♀ 8-X-1942 [no other data]; 1 ♀ [no data]. ATLFO.

Chrysops striatus Osten Sacken, 1875 – Canada: 1 ♀ (1) “24-VI-1931 Ont. [Ontario] | Pt. [Point], Pelee” (2) “G.S. Walley”; 1 ♀ (1) “12-VIII-1943 Ont. [Ontario] | Marmora” (2) “G.H. Hammond”.

Chrysops univittatus Macquart, 1855 – Canada: 1 ♀ (1) “22-VI-1925 Ont. [Ontario] | Low Bush, Lake Atibiti” (2) “N.K. Bigelow”; 1 ♀ (1) 24-VIII-1952 Ont. [Ontario] | Marmora” (2) “J.R. Vockeroth”. USA: 1 ♀ (1) “12-VI-1936 New Jersey | Brows Mills” (2) “E.L. Pechuman”; as *Chrysops wiedemanni* Kröber – 1 ♀ (1) “24-VI-1936 N. Y. [New York] | Lockport” (2) “L.L. Pechuman”.

Chrysops varians Wiedemann, 1828 – Brazil: 1 ♀ (1) “14/15-XI-1979 Pará | Paragominas | PA Km 32”; 1 ♀ (1) “IV-1972 Pernambuco | Caruaru”; 1 ♀ (1) “10-VIII-1951, 1 ♀ (1) “14-IX-1951” Bahia | Salvador”; 1 ♀ (1) “27-X-1950 Rio de Janeiro | Rio de Janeiro | Sernambetiba”; 7 ♀♀ [no date] all specimens with label (1) “Rio de Janeiro | Teresópolis”; 2 ♀♀ (1) “PROC Nº 11⁄528” each one; 2 ♀♀ (1) “PROC Nº 11⁄531”, each one; (1) “PROC Nº 11⁄533”; 2 ♀♀ (1) “PROC Nº 11⁄534” each one; 1 ♀ (1) “PROC Nº 11⁄540”; 1 ♀ (1) “21-II-1917 PROC Nº 11⁄537” (2) “São Paulo | São Paulo, Av. [Bosque] da Saúde”;

2 ♀♀ (1) “I-1971”, 1 ♀ (1) “XI-1972 Minas Gerais | Pedra Azul”; 2 ♀♀ (1) “III-1971 Santa Catarina | Curitibanos”; 1 ♀ (1) “XII-1973 Goiás | Campinas” [Goiânia]” (2) “EMBRAPA”. ATLFO.

Chrysops variegatus (DeGerr, 1776) – Cuba: 1 ♀ (1) “I-1934 Cuba | Habana”. French Guiana: 1 ♀ (1) “1914 French Guiana | Charvein” (2) “Museum Paris”. Brazil: 1 ♀ (1) “I-1950 Amazonas | Alto Itacoaí”; 5 ♀♀ (1) “VII-VIII-1940 Pará | Belém, Aurá”; 1 ♀ (1) “6⁄11-VI-1966 Pará | Belém” (2) “EMBRAPA”; 3 ♀♀ (1) “V-1969 Ceará | Barbalha”; 15 ♀♀ (1) “V-1972 Pernambuco | Caruaru”; 4 ♀♀ (1) “XI-1972 Goiás | Jataí”; 2 ♀♀ (1) “I-1929” Bahia | Ilha de Bom Jesus”; 1 ♀ (1) “20-VIII-1951 Bahia | Salvador”; 1 ♀ (1) “XI-1903 Mato Grosso | Oeste”; 1 ♀ (1) “XI-1973 Mato Grosso | Bodoquena” (2) “IOC”; 29 ♀♀ (1) “XI-1972 Minas Gerais | Pedra Azul”; 1 ♀ (1) “8-XI-1944 Rio de Janeiro | Rio de Janeiro | Deodoro” (2) “EMBRAPA”; 2 ♀♀ [no date] both with label (1) “Rio de Janeiro | Xerém”; 1 ♀ [no date] (1) “Nº 11⁄543”. ATLFO.

Chrysops venus Philip, 1950 – Canada: 1 ♀ (1) “10-II-1965 Ont. [Ontario] | Maynooth” (2) “J.F. Mc Alpine”; 1 ♀ (1) “23-VI-1951 Que. [Quebec] | Beechgrove” (2) “Mc Alpine”.

Chrysops vittatus Wiedemann, 1821 – Canada: 1 ♀ (1) “28-VI-1942”, 1 ♀ (1) “16-VI-1952” Ont. [Ontario] | Ottawa” (2) “J.R. Vockeroth”. USA: 1 ♀ (1) “22-VI-1939” N. Y. [New York] | Olcott” (2) “L.L. Pechuman”. Brazil: 1 ♀ (1) “XII-1959 Terr. Amapá | Serra do Navio” (2) “Bicelli Col”.

Chrysops wiedemanni Kröber = *Chrysops univittatus* Macquart, 1855.

Unidentified specimens of Genus *Chrysops*: 60.

Genus *Orgizomyia* Grünberg, 1906

Orgyzomyia zigzag (Macquart, 1855) – Madagascar: 1 ♀ (1) “1902 Museum Paris | Ikongo | G. Grandier 1902” (2) “1479”; 1 ♀ (1) “I-1931 Madagascar | F$^+$, D.A. Seyrig” (2) “2750”.

Genus *Silvius* Meigen, 1820

Silvius alpines (Scopoli, 1763) as *Silvius vituli* – France: 1 ♀ (1) “VII-1894 Thones” [Thônes] (2) “Museum Paris | Coll. E. Séguy” (3) “2746”.

Tribus Rhinomyzini Enderlein, 1922

Genus *Aegophagamyia* Austen, 1912

Subgenus *Triclida* Enderlein, 1923

Aegophagamyia (Triclida) variegata Surcouf, 1908 as *Bouvierella variegata* Walker – Madagascar: 1 ♀ [no date] (1) “[Ilegible] | A. Seyrig” (2) “2788”; 1 ♀ [no date] (1) [Ilegible] “A. Seyrig” (2) “*Bouvierella variegata* Scf. | Surcouf det” (3) “1828”.

Subfamilia Pangoninae Loew, 1860

Tribus Pangoniini Enderlein, 1922

Genus *Corizoneura* Rondani, 1863 = Genus *Philoliche* Wiedemann, 1828

Corizoneura dorsalis Macquart = *Philoliche neocaledonica* Mégnin, 1878.

Genus *Pangonius* Latreille, 1802

Pangonia maculata = *Pangonius mauritanus* (Linnaeus, 1767).

Pangonia micans = *Pangonius* (*Melanopangonius*) *micans* Meigen, 1820

Pangonius leucomelame Seguy = *Philoliche (Dorcaloemus) fodiens* Austen, 1908.

Pangonius magretti = *Philoliche magrettii* Bezzi, 1901.

Pangonius mauritanus (Linnaeus, 1767) as *Pangonia maculata* – Morocco: 1 ♀ (1) “22-V-1928 Museum Paris | Maroc | Foret des Zaërs [Rabat-Salé-Kénitra, Forêt de Maâmora] | Ain Sterguilla [?] | R. Benoist 1928” (2) “2747”.

Pangonius rhynchocephalus (Kröber, 1921) – Ethiopia: 1 ♀ (1) “VI-1902 Museum Paris | Fleunne [?] Omo | pouces meridis del Abyssinie | E. Brumpt | 1906” (2) “2825”.

Subgenus *Melanopangonius* Szilady, 1923

Pangonius (*Melanopangonius*) *micans* Meigen, 1820 as *Pangonia micans* – France: 1 ♀ [no date] (1) “2751”; as *Therioplectes micans* – 1 ♀ [no date] (1) “Hautes Vosges | Hineck [Le Honneck], 1366m | La Schulucht 1,150 m” (2) “EMBRAPA”.

Genus *Therioplectes* Zeller, 1842

Therioplectes affinis Kirby = *Hybomitra affinis* (Kirby, 1837).

Therioplectes micans = *Pangonius* (*Melanopangonius*) *micans* Meigen, 1820.

Therioplectes microcephalus = *Hybomitra microcephala* (Osten Sacken, 1876).

Therioplectes zonalis = *Hybomitra zonalis* (Kirby, 1837).

Unidentified specimens of *Therioplectes*: 9.

Tribus Philolichini Mackerras, 1954

Genus *Philoliche* Wiedemann, 1828

Philoliche magrettii Bezzi, 1901 as *Pangonius magretti* – [Republic of Mozambique]: 1 ♀ (1) “1929 Museum Paris | Zambeze [River] [Manica] | Amont de Tambara | Njanassé Lac Msica | P. Lesne 1929” (2) “2826”.

Philoliche neocaledonica Mégnin, 1878 as *Corizoneura dorsalis* Macquart, 1838 – New Caledonia: 1 ♀ (1) “1902 Museum Paris | Nouvelle Calédonie | Bourail | H. Méray, 1902” (2) “2741”; 1 ♀ (1) “3-IV-1902 Oubatelse” [?] (2) “2742”.

Subgenus *Dorcaloemus* Austen, 1910

Philoliche (Dorcaloemus) fodiens Austen, 1908 as *Pangonius leucomelame* Seguy – Zambeze: 1 ♀ (1) 1928 Museum Paris | Zambeze | Amont de Tambara | Alfate [Alfaiate] Gare | P. Lesne 1928” (2) “2801”.

Subfamily Pangoniinae Rondani | 1856

Tribe Pangoniini Rondani, 1856

Genus *Esenbeckia* Rondani, 1863

Subgenus *Esenbeckia* Rondani, 1863

Esenbeckia (Esenbeckia) esenbecki Wiedemann, 1830 – Brazil: 1 ♀ (1) “22/25-III-1979 “Goiás | Distrito Federal | Reserva Ecológica do DF”.

Esenbeckia (Esenbeckia) fuscipennis (Wiedemann, 1828) – Brazil: 1 ♀ (1) “II-1910 “Minas Gerais | Benjamin Constant”; 1 ♀ (1) “XII-1933 Minas Gerais | Cambuquira” (2) “EMBRAPA”; 7 ♀♀ (1) “2-III-1903 Minas Gerais | São Paulo de Muriaé”; 3 ♀♀ (1) “7-VI-1916, 2 ♀♀ (1) “XII-1913”, 1 ♀ (1) “I-1933” Rio de Janeiro | Angra dos Reis | Japuhiba” (2) “EMBRAPA”; 2 ♀ (1) “I- 1932 Rio de Janeiro | Angra dos Reis” (2) “EMBRAPA”; 2 ♀♀ (1) “1-III-1914 Rio de Janeiro |

Petrópolis"; 1 ♀ (1) "III-1956 Rio de Janeiro | Petrópolis | Alto Mosela"; 1 ♀ (1) "1932 Rio de Janeiro | Tijuca" (2) "EMBRAPA"; 1 ♀ (1) "1902 Rio de Janeiro [Itatiaia] | Serra dos Órgãos | 500 a 900 m"; 1 ♀ (1) "9-III-1913 Rio de Janeiro | Teresópolis"; 1 ♀ [no date] (1) "Xerém" [Rio de Janeiro, Duque de Caxias]; 1 ♀ (1) "XII-1933 São Paulo | Cambuquira" (2) "EMBRAPA"; 1 ♀ (1) "1930 Santa Catarina | Nova Teutônia" (2) "EMBRAPA". ATLFO.

Esenbeckia (Esenbeckia) orsonoi Fairchild, 1942 as *Esenbeckia orsonoi guyanensis* – Brazil: 1 ♀ (1) "16-V-1983 Pará | Serra Norte | Estrada do Manganês".

Esenbeckia (Esenbeckia) perspicua Wilkerson & Fairchild, 1983 – Brazil: 25 ♀♀ (1) "X-1975 Mato Grosso | Sinop"; 11 ♀♀ (1) "14-XI-1958 Mato Grosso | Jacaré".

Esenbeckia (Esenbeckia) aff. perspicua – Brazil: 3 ♀♀ (1) "14-III-1958 Mato Grosso | Jacaré".

Esenbeckia (Esenbeckia) prasiniventris (Macquart, 1846) – Brazil: 1 ♀ [no date] (1) "Nº 11/497".

Esenbeckia (Esenbeckia) vulpes (Wiedemann, 1828) – Brazil: 1 ♀ (1) "15-XII-1938 Minas Gerais | Fortaleza" [de Minas]. ATLFO.

Unidentified specimens of Genus *Esenbeckia*: 13.

Genus *Thaumastocera* Grünberg, 1906

Thaumastocera akwa Grünberg, 1906 – Gabon: 1 ♀ (1) "1913 Museum Paris | Ogooué | Lambaréne | R. Ellenberger 1913" (2) "D'Albuquerque det" (3) "2862".

Tribe Scepsini Bequaert, 1930

Genus *Scepsis* Walker, 1850

Scepsis nivalis = *Scepsis appendiculata* (Macquart, 1840).

Scepsis appendiculata (Macquart, 1840) as *Scepsis nivalis* Walker, 1850 – Brazil: 2 ♀♀ (1) "21-IV-1936 Rio de Janeiro | Rio de Janeiro | Praia da Gávea". ATLFO.

Tribe Scionini Enderlein, 1922

Genus *Fidena* Walker, 1850

Subgenus *Fidena*, 1850

Fidena aurifasciata = *Fidena (Fidena) nigripes* (Röder, 1886).

Fidena (Fidena) aurimaculata (Macquart, 1932) – Brazil: 1 ♀ NEOTYPE (1) "21-II-1942 Rio de Janeiro | Itatiaia | Fazenda Penedo". ATLFO.

Fidena (Fidena) bocainensis (Lutz & Castro, 1936) – Brazil: 2 ♀♀ (1) "9-VI-1918 Minas Gerais | Virginia". ATLFO.

Fidena (Fidena) brachycephala Kröber, 1931 – Brazil: 1 ♀ NEOTYPE [no data, no label, without head].

Fidena (Fidena) brasiliensis Krober, 1931 – Brazil: 1 ♀ (1) "I-1932 Rio de Janeiro | Angra dos Reis" | *Erephopsis brasiliensis*" (2) "Nº 1458". ATLFO.

Fidena (Fidena) castanea (Perty, 1833) – Ecuador: 2 ♀♀ NEOTYPES [no date, no procedence] (1) "Museum Paris". Brazil: 1 ♀ (1) "VI-1944 Mato Grosso" [Mato Grosso do Sul] | Palmeiras" [Aquidauana] (2) "Zoppei Col | 169"; 1 ♀ (1) "III-194[?] Bodoquena | Com. Inst O. Cruz | *Fidena castanea* Castro det"; 2 ♀♀ (1) "III/IV-1944 Porto Cabral | Rio Paraná"; 3 ♀♀ NEOTYPES [no data, no label]. ATLFO.

Fidena (Fidena) decipiens Kröber, 1931 – Brazil: 7 ♀♀ (1) "I-1937 São Paulo | Bananal | Serra da Bocaina"; 1 ♀ (1) "XI-1929, 1 ♀ (1) "XI-1903" Itatiaia"; 1 ♀ (1) "1-III-1924 Rio de Janeiro | Friburgo". ATLFO.

Fidena (Fidena) eriomera (Macquart, 1838) – Brazil: 1 ♀ (1) "19-III-1911 Amazonas | Manaus | Vila do Aleixo"; 1 ♀ [no date, no procedence] (1) "PROC 11/472"; 2 ♀♀ (1) "20-III-1903 Cachorrinha [?]. Paraguay: 1 ♀ (1) "4-III-1910 Alto Paraná".

Fidena (Fidena) erythronotata (Bigot, 1892) – Brazil: 1 ♀ NEOTYPE (1) "18-XII-1919 São Paulo | Guarujá | Perequê"; 1 ♀ (1) "III-1915 Minas Gerais | Caxambu" (2) "PROC 11/470"; 1 ♀ [no date] (1) "PROC 11/471". ATLFO.

Fidena (Fidena) freemani Barreto, 1957 – Brazil: 121 ♀♀ (1) "XI-1973 "Rondônia | Vilhena".

Fidena (Fidena) fumifera Walker, 1854 – Brazil: 1 ♀ (1) "22-IV-1955", 1 ♀ "27-XI-1955", 1 ♀ "5-VIII-1956", 1 ♀ "5-XI-1957", 1 ♀ "17-XI-1957", 13 ♀♀ "20-XI-1957", 1 ♀ "25-XI-1957", 2 ♀♀ "29-XI-1957" Amazonas | Manaus"; 1 ♀ (1) "20-VI-1985 Pará | Serra Norte".

Fidena (Fidena) fusca (Thunberg, 1827) – Brazil: 1 ♀ (1) "23-XI-1958 Amazonas, Manaus"; 1 ♀ (1) 25-III-1919 Minas Gerais | Virginia | Faz. dos Campos | Sul de Minas"; 1 ♀ [no date] (1) "Minas Gerais | Virginia | Sul de Minas" (2) "PROC 11/506"; 1 ♀ [no date] (1) "Minas Gerais | Passa Quatro | Serra dos Cochos"; 1 ♀ (1) "9-IX-1917" "Espírito Santo | Caparaó"; 1 ♀ (1) "17-III-1915 Espírito Santo | Vista do Alegre"; 3 ♀♀ (1) "XI-1909 Rio de Janeiro | Itatiaia | Morro dos Cardosos"; 1 ♀ (1) 08-XII-1930 Rio de Janeiro | Itatiaia | Estação de Biologia"; 82 ♀♀ (1) "8/10-III-1951 Rio de Janeiro | Itatiaia | 1300 a 1830 m"; 19 ♀♀: (1) "19-III-1924", "23-II-1925", "5-III-1929", "7-III-1929", "24-II-1930", "28-III-1931", "29-VI-1932", "03-III-1932", "19-III-1932", "2-IV-1932", "24-III-1934", "29-III-1935", "17-III-1937", "26-III-1937", "6-III-1939", "19-II-1940", "17-III-1941", "29-XI-1933", "13-XII-1936"; 5 (1) ♀ "6/10-XII-1950", 1 ♀ (1) "6-VI-1954", 1 ♀ (1) "13-XII-1968 all from "Rio de Janeiro Itatiaia"; 3 ♀♀ [no date] with labels (1) "Rio de Janeiro | Itatiaia" (2) "Inst. 1121" (2) "Inst. 1132" (2) "Inst. 140", each one; 3 ♀♀ (1) "3-III-1910", "III-1913", "1-III-1914" Rio de Janeiro | Petrópolis"; 3 ♀♀ (1) "3-II-1917 Rio de Janeiro | Teresópolis"; 1 ♀ (1) "13-X-1936", 1 ♀ (21) "21-III-1924 Rio de Janeiro | Nova Friburgo"; 1 ♀ (1) "XII-1917 São Paulo | Angatuba"; 1 ♀ (1) "28-II-1915 São Paulo | Bananal | Serra da Bocaina"; 1 ♀ (1) "III-1914 São Paulo, Bocaina | Faz do Bonito"; 1 ♀ (1) "IV-1939 São Paulo | Casa Grande"; 1 ♀ (1) "3-X-1938 São Paulo | Campos do Jordão"; 1 ♀ [no date] (1) "São Paulo | São Paulo | Ipiranga"; 1 ♀ (1) "II-1917 Paraná | S.S. Araújo"; 2 ♀♀ [no date, no procedence] with label (1) "Inst. 1403" each one; 1 ♀ [no data, no label]. ATLFO.

Fidena (Fidena) leonina (Lutz, 1909) – Brazil: 1 ♀ (1) "31-III-1917", 4 ♀♀ (1) "9-III-1918 Minas Gerais | Passa Quatro"; 3 ♀♀ (1) "10-II-1917 São Paulo | Bananal | Serra da Bocaina | Faz do Bonito"; 7 ♀♀ (1) "VII-1970 Santa Catarina | Curitibanos". ATLFO.

Fidena (Fidena) leucopogon (Wiedemann, 1828) – Brazil: 1 ♀ (1) "XII-1957 Santa Catarina | Brusque | 174, SC" (2) "*Fidena leucopogon* Wied. | J. Lane Col"; 5 ♀♀ NEOTYPES [no date] all with label "Rio de Janeiro | Rio de Janeiro | Tijuca | 93-3". ATLFO.

Fidena (Fidena) longipalpis Enderlein, 1925 – Brazil: 18 ♀♀ (1) |"VIII-1970", 1 ♀ (1) "III-1971" all specimens with label (1) "Santa Catarina | Curitibanos". ATLFO.

Fidena (Fidena) loricornis Kröber, 1931 – Brazil: 1 ♀ NEOTYPE (1) "II-1934 Rio de Janeiro | Petrópolis" [probably misidentified]; 1 ♀ (1) "19-XI-1976 Amazonas | Manaus | Rodovia AM 010 Km 30").

Fidena (Fidena) marginalis (Wiedemann, 1830) – Brazil: 1 ♀ NEOTYPE [no date] (1) “Minas Gerais | Virginia” | “PROC 10/992”. ATLFO.

Fidena (Fidena) nigripennis (Guérin-Méneville, 1832) – Brazil: 2 ♀♀ (1) “18-III-1914”, 1 ♀ (1) “11-III-1914”, 2 ♀♀ (1) “14-III-1914 Espírito Santo | Alegre”; 1 ♀ (1) “1/8-IV-1907 Rio de Janeiro | Jacutinga” (2) “*Erephopsis nigripennis* Guerin, 1932 | *Welpia nigripennis* Guer.”; 1 ♀ [no date, no precedence] (1) “Inst. 1179”; 1 ♀ (1) “1-III-1910 Rio de Janeiro | Petrópolis”. ATLFO.

Fidena (Fidena) nigripes (Röder, 1886) as *Fidena aurifasciata* Enderlein, 1925 – Brazil: 1 ♀ NEOTYPE (1) “21-II-1942 Rio de Janeiro | Itatiaia | Fazenda Penedo” [no right wing]; as *Fidena longirostris*, 1 ♀ (1) “15-VIII-1936 São Paulo | Mogi das Cruzes” | (2) “172”| (3) “*Fidena longirostris,* Castro”. ATLFO.

Fidena (Fidena) nitens (Bigot, 1892) – Brazil: 2 ♀♀ NEOTYPES: 1 ♀ (1) “5-VI-1926”, 1 ♀ (1) “14-VI-1930 Rio de Janeiro | Itaguaí”. ATLFO.

Fidena (Fidena) nubiapex (Lutz, 1911) – Brazil: 2 ♀♀ NEOTYPES: 1 ♀ (1) “27-III-1920 “Minas Gerais | Virginia”; 1 ♀ (1) “18-III-1929 Rio de Janeiro | Itatiaia, 700 m”. ATLFO.

Fidena (Fidena) obscuripes Kröber, 1931 – Brazil: 1 ♀ [no date] (1) “Rio Grande do Sul | *Fidena obscuripes* det Castro | RGS”.

Fidena (*Fidena*) *opaca* (Brèthes, 1910) – Brazil: 1 ♀ [no date] (1) “Tucuman” | Arnau | *convergens* | *F. (F.) opaca* = *convergens* Enderl”.

Fidena (Fidena) penicillata (Bigot, 1892) – Brazil: 4 NEOTYPES ♀♀ (1) “XII-1946”, 1 ♀ (1) “20-III-1946”, 8 ♀♀ (1) “XII-1946”, 4 ♀♀ (1) “XII-1948”, 12 ♀♀ (1) “IV-1957”, 3 ♀♀ (1) “20-III-1958” all specimens with label (1) “São Paulo | Boraceia”; 8 ♀♀ (1) “I-1937 São Paulo, Bananal | Serra da Bocaina”; 2 ♀♀ (1) “II-1922 São Paulo | Santos | Serra de Santos” (2) “Oswal 1336”; 1 ♀ (as *Fidena Braziliensis*) (1) “XI-1940 RJ [Rio de Janeiro] Tinguá | S.F.A. Col” (2) “175”. ATLFO.

Fidena pseudomaculata = *Fidena (Fidena) pseudoaurimaculata* (Lutz, 1909).

Fidena (Fidena) pseudoaurimaculata (Lutz, 1909) as *Fidena pseudomaculata* – Brazil: 1 ♀ (1) “24-VIII-1975 Pará | Fofoca | Serra Norte”; 1 ♀ (1) “23-IX-1957 Amapá | Serra do Navio | K. Lenko leg” (2) “*Fidena pseudoaurimaculata* Lutz | Det Fairchild, 1958 | AP”.

Fidena (Fidena) rufohirta (Walker, 1848) – Brazil: 2 ♀♀ NEOTYPE [no date] (1) “Rio de Janeiro | Petrópolis” (2) “EMBRAPA”; 1 ♀ NEOTYPE (1) “10-XII-1950 Rio de Janeiro | Itatiaia”; 1 ♀ (1) “23-III-1923 [no procedence] (1) “PROC 11/105”. ATLFO.

Fidena (Fidena) sorbens (Wiedemann, 1828) – Brazil: 1 ♀ (1) “X-1957 Amazonas | Manaus | Reserva Duke”; 1 ♀ (1) “VII-1909 Minas Gerais | Alfenas”; 2 ♀♀ (1) 16-XII-1910 Minas Gerais | Benjamin Constant”; 1 ♀ (1) “23-VIII-1915 Minas Gerais | Passa Quatro”; 5 ♀♀ (1) “7-V-1915 Minas Gerais | Ouro Fino | Estrada do Comércio”; 1 ♀ “6-II-1970 Minas Gerais | Santa Barbara | Serra do Caraça”; 1 ♀ [no date] (1) “Minas Gerais | Jaguará” (2) “Nº 11/504”; 1 ♀ [no date] (1) “Minas Gerais | Paraopeba” (2) “Nº 16305”; 1 ♀ [no date] (1) “Minas Gerais | Virginia” (2) “PROC Nº 11⁄513”; 1 ♀ (1) “II-1902 Rio de Janeiro | Itatiaia | Mont Serrat” (2) “Nº 11/517”; 1 ♀ (1) “VIII-1902 Rio de Janeiro | Itatiaia | Mont Serrat”; 1 ♀ (1) “25/30-IX-1913 Rio de Janeiro | Itatiaia”; 3 ♀♀: (1) “18-III-1929”, “28-1-1933”, “17-VI-1934” Rio de Janeiro | Itatiaia”; 1 ♀ (1) “22-VI-1937 Rio de Janeiro | Rio de Janeiro | Deodoro” (2) “EMBRAPA”; 1 ♀ (1) “9-IV-1942 Rio de Janeiro | Seropédica Km 47”; 1 ♀ (1) “1-II-1956 Rio de Janeiro | Petrópolis | Alto Mosela”; 1 ♀ (1) “25/30-IX-1913 São Paulo | Serra da Bocaina | Faz do Bonito”; 1 ♀ (1) “28⁄30-IX-1913 São Paulo | Bananal | Serra da Bocaina”; 2 ♀♀ (1) “III-1934 São Paulo | Sertãozinho”; 1 ♀ (1) “4-VI-1910 “NT 1210 Inst. O. Cruz | Coleção A. Lutz”; 1 ♀ (1) “16-XII-1910 NT 1210 Inst. O. Cruz | Coleção A. Lutz”; 1 ♀ [no date] (1) “Inst. O. Cruz | Coleção A. Lutz”; 1 ♀ [no date] (1) “PROC 11⁄514”; 1 ♀ [no date] (1) “PROC Nº 11⁄516”. ATLFO.

Fidena (Fidena) venosa (Wiedemann, 1821) – Brazil: 1 ♀ NEOTYPE [no label].

Fidena (Fidena) winthemi (Wiedemann, 1819) – Brazil: 1 ♀ (1) “III-1934 Espírito Santo | Vitória” (2) Serviço Febre Amarela M.E.S. Brazil | ES”; 1 ♀ (1) “XII-1931 Rio de Janeiro | Angra dos Reis” (2) “Osw 1937 | RJ”; 1 ♀ (1) “I-1932 Rio de Janeiro | Angra dos Reis”; 1 ♀ NEOTYPE (1) “17-VI-1934 Rio de Janeiro | Itatiaia”; 1 ♀ (1) “XII-1930 RJ [Rio de Janeiro, Rio de Janeiro] Botafogo | L.T.F. Col” (2) “E.S.A.N. 122”; 1 ♀ NEOTYPE (1) “05-VI-1943 = *picea*” (2) “Rio de Janeiro | Seropédica, Km 47”; 1 ♀ (1) ”I-1939 São Paulo | Mogi das Cruzes | SP”; 1 ♀ [no date] (1) “PROC 11/020”. ATLFO.

Unidentified specimens of Genus *Fidena*: 245.

Genus *Pityocera* Giglio-Tos, 1896

Thera are 160 specimens of *Pityocera* with no identification.

Genus *Scaptia* Walker, 1850

Subgenus *Lepmia* Fairchild, 1969

Scaptia (Lepmia) molesta (Wiedemann, 1828) – Brazil: 5 ♀♀ (1) “VII-1932” [no procedence] “PROC 11/479”, “PROC 11/480”, “PROC 11/481”, “PROC 11/482”, “PROC 11/484”, each one.

Scaptia (Lepmia) seminigra (Ricardo, 1902) – Brazil: 2 ♀♀ (1) “VII-1932 Rio de Janeiro | Angra dos Reis”. ATLFO.

Subgenus *Myioscaptia* Mackerras, 1955

Scaptia (Myioscaptia) violacea (Macquart, 1850) – Australia: 1 ♀ (1) “XI-1920 Winghan [North South Wales] Pfeiffer | *Diatomineura violacea* Macquart”.

Subgenus *Pseudoscione* Lutz, 1918

Scaptia (Pseudoscione) fenestrata (Macquart, 1846) – Brazil: 4 ♀♀ [no date] all specimens with labels (1) “PROC 11/478”, “PROC 11/488”, “PROC 11/489”, “PROC 11/490”, each one.

Scaptia (Pseudoscione) longipennis (Ricardo, 1902) – Brazil: 1 ♀ (1) “VII-1909 Minas Gerais | Alfenas” (2) “PROC Nº 11/477”; 1 ♀ [no date] (1) “Minas Gerais | Virginia | Faz. Campos, 1500 m” (2) “PROC 11/478”; 1 ♀ [no date] (1) “Santa Catarina | Nova Teutônia” (2) “BEM”; as *Diatomineura albanipennis* [in error, the correct synonym is *D. longipennis*] – 1 ♀ [no date] (1) “Rio de Janeiro | Xerém” (2) “Oswaldo Cruz 1451”. ATLFO.

Subgenus *Scaptia* Walker, 1850

Scaptia (Scaptia) auriflua (Donovan, 1805) – Australia: 1 ♀ (1) 1911 Museum Paris | Australie, Etat de Victoria | Riv. Nicholson et Riv. Tambo | F. Gfeay | *Diatomineura auriflua* Don.” (2) “2875”.

Scaptia (Scaptia) lata (Guérin-Mneville, 1838) – Chile: 3 ♀♀ (1) “II-1970 Concepción | Parq. Bot. Hualpen”; 1 ♀ (1) “19-VI-1934 Las Mercedes”; 1 ♀ (1) “II-1912 “Llanquihue”; 1 ♀ (1) “1941 Santiago”. Brazil: 2 ♀♀ (1) “II-1970 Minas Gerais | Santa Vitória”.

Scaptia (Scaptia) rufa Philip, 1969 – Chile: 1 ♀ (1) "10-VI-1935 (1) Las Mercedes".
Unidentified specimens of Genus *Scaptia*: 32.

Subfamily Tabaninae Latreille, 1802
Tribe Diachlorini Lutz, 1909
Genus *Acanthocera* Macquart, 1834
Subgenus *Acanthocera* Macquart, 1834

Acanthocera (Acanthocera) anacantha Lutz & Neiva, 1915 – Brazil: 1 ♀ (1) "IV/V-1937 Mato Grosso │ Maracujá │ Fairchild det 1938"; 1 ♀ (1) "XII-1935 Goiás │ Campinas" (2) "EMBRAPA" (3) "S. Lopes"; 1 ♀ [no date] (1) "São Paulo │ Vera Cruz" (2) "179, SP". ATLFO.
Acanthocera (Acanthocera) aureoscutellata Henriques & Rafael, 1992 – Brazil: 1 ♀ (1) "I-1937 Bananal │ Serra da Bocaina" (2) "EMBRAPA" (3) "Henriques". ATLFO.
Acanthocera (Acanthocera) fairchildi Henriques & Rafael, 1992 – Brazil: 1 ♀ (1) "8-X-1972 Mato Grosso │ Aripoanã".
Acanthocera (Acanthocera) gorayebi Henriques & Rafael, 1992 – Brazil: 1 ♀ (1) "2⁄5-VIII-1987 Maranhão │ Imperatriz │ Ribeirãozinho".
Acanthocera (Acanthocera) longicornis (Fabricius, 1775) – Brazil: 1 ♀ (1) "X-1972 "Espírito Santo │ Conceição da Barra │ Novo Horizonte"; 1 ♀ [no date] (1) "Vitória"; 1 ♀ (1) "XII-1931 Rio de Janeiro │ Angra dos Reis" (2) "Osw. 1435"; 1 ♀ (1) "24-XI-1948 Rio de Janeiro │ Seropédica, [Antiga] Est. Rio São-Paulo Km 47"; 1 ♀ (1) "19-XI-1961 Rio de Janeiro │ Barra da Tijuca"; 1 ♀ [no date] (1) "[Rio de Janeiro, Rio de Janeiro] L. Taxas [Canal das Tachas], R [Recreio dos] Bandeirantes"; 1 ♀ [no date] (1) "Rio de Janeiro │ Jacarepaguá" (2) "Nº 11 PROC 624"; 1 ♀ (1) "II-1935", 1 ♀ (1) "6-VI-1935 Rio de Janeiro │ Deodoro"; 1 ♀ (1) "16-VI-1938 Rio de Janeiro │ Deodoro" (2) "EMBRAPA"; 1 ♀ (1) "II-1940 Rio de Janeiro │ Deodoro" (2) "EMBRAPA"; 1 ♀ (1) "29-XI-1920 Teresópolis │ Vargem de Teresópolis" (2) "MUSEU NACIONAL"; 1 ♀ [no date] (1) "Rio [de Janeiro], RJ" (2) "181"; 1 ♀ (1) "13-i1965 Paraná │ Antonina │ 1-10:00 hs, nublado"; 1 ♀ [no date] (1) "Nº 20 PROC 004". ATLFO.
Acanthocera (Acanthocera) marginalis Walker, 1854 – Brazil: 1 ♀ (1) "21⁄25-X-1988 Amazonas │ Maraã │ Maguari".

Subgenus *Nothocanthocera* Fairchild, 1969

Acanthocera (Nothocanthocera) nigricorpus Lutz, 1915 – Brazil: 1 ♀ [no date] (1) "Inst. Biolog. Entomologia Agricola Rio de Janeiro".
Unidentified specimens of Genus *Acanthocera*: 5.

Genus *Bolbodimyia* Bigot, 1892

Bolbodimyia brunneipennis Stone, 1954 – Brazil: 2 ♀♀ (1) "3-VI-1957 Amapá │ Rio Amapari" (2) "289".

Genus *Catachlorops* Lutz, 1913
Subgenus *Amphichlorops* Lutz, 1913

Catachlorops (Amphichlorops) flavus (Wiedemann, 1828) – Brazil: 1 ♀ (1) "I-1932 Rio de Janeiro │ Angra dos Reis" (2) "Osw 1511"; 2 ♀ (1) "XI-1932 Rio de Janeiro │ Angra dos Reis" (2) "Osw 1511" and (2) "Osw 1514", each one; 2 ♀♀ (1) "20/21-XII-2013 Rio de Janeiro │ Mangaratiba │ Ilha da Marambaia" │ Guimarães Col".; 1 ♀ (1) "IX-1913 [São Paulo] Bocaina, Rio Mabual" (2) "Osw 1318"; 1 ♀ (1) "XI-1929 Juquiá │ J. Lane". ATLFO.
Catachlorops (Amphichlorops) immaculatus (Macquart, 1838) – Brazil: 1 ♀ (1) "X-1936 Rio de Janeiro │ Angra dos Reis │ Japuhiba" (2) "Trav. & Lopes [col]"; 1 ♀ "XII-1933 Rio de Janeiro │ Itatiaia, 800 m" (2) "Lopes & Cunha Col"; 2 ♀♀ (1) "I-1933 Rio de Janeiro │ Rio [de Janeiro] Represa Carmorim" (2) "L.T.F. Col"; 1 ♀ (1) "I-1941 São Paulo │ Piedade" (2) "809" (3) "Barreto Col"; 1 ♀ [no date] (1) "Osw 1517". ATLFO.

Subgenus *Catachlorops* Lutz, 1913

Catachlorops (Catachlorops) fuscinevris (Macquart, 1838) – Brazil: São Paulo: 2 ♀♀ (1) "II-1910 Bonito" (2) "Osw 1299"; 2 ♀♀ (1) "2-XI-1947 Iguapé SP". ATLFO.
Catachlorops (Catachlorops) leptogaster Barreto, 1946 – Brazil: 3 ♀♀ (1) "20/21-XII-2013 Rio de Janeiro │ Mangaratiba │ Ilha da Marambaia │ Guimarães col". ATLFO.
*Catachlorops (Catachlorops) luctuosus (*Macquart, 1838) – Brazil: 1 ♀ (1) "XII-1932 (1) "Rio de Janeiro │ Angra dos Reis, RJ". ATLFO.
Catachlorops (Catachlorops) potator (Wiedemann, 1828) – Brazil: 13 ♀♀ (1) "X-1934 Rio de Janeiro [Seropédica], [Antiga] Rod. Rio-São Paulo, Km 47" (2) "EMBRAPA"; 1 ♀ (1) "I-1911 São Paulo │ Formoso │ Serra da Bocaina" (2) "Osw 1309"; 2 ♀♀ (1) "24-XI-1947 "São Paulo │ Iguapé, SP"; 1 ♀ [no date] (1) "Osw 1481". ATLFO.
Catachlorops (Catachlorops) psolopterus (Wiedemann, 1828) – Brazil: 1 ♀ (1) "II-1912 Minas Gerais │ Pacau" (2) "Osw 1499"; 1 ♀ (1) "XII-1931 Rio de Janeiro │ Angra dos Reis" (2) "Osw 1498"; 2 ♀♀ (1) "I-1932 Rio de Janeiro │ Angra dos Reis" (2) "Osw 1507" and (2) "1457", each one; 1 ♀ (1) "30-VI-1910 Rio de Janeiro │ Petrópolis, RJ" (2) "Osw 11295" (3) "RJ"; as *Catachlorops psoloptera* [in error, probably originated from Martins (1940) and Barreto (1946), the correct form is *C. psolopterus*]; 2 ♀♀ (1) "1-V-1911 São Paulo │ Formoso │ Serra da Bocaina" (2) "Osw. 1296" and (2) "1297" each one; 1 ♀ (1) "Osw 1456". ATLFO.
Catachlorops (Catachlorops) rufescens Fabricius, 1805 – Bolivia 1 ♀ [no date] (1) "Bogotá de Santa Fé".

Subgenus *Psalidia* Enderlein, 1922

Catachlorops (Psalidia) conspicua = *Catachlorops* (*Psalidia*) *conspicuus* (Lutz & Neiva, 1914).
Catachlorops (*Psalidia*) *conspicuus* (Lutz & Neiva, 1914) as *Catachlorops conspicua* – Brazil: 2 ♀♀ (1) "I-1932 Rio de Janeiro, Angra dos Reis" (2) "Osw 1508" and (2) "Osw 1510", each one. ATLFO.
Catachlorops (*Psalidia*) *furcatus* (Wiedemann, 1828) – Brazil: São Paulo: 1 ♀ (1) "I-1943 Iguapé" (2) "215, "SP" (3) "H. Ramalho"; 1 ♀ (1) V-1907 Santos". ATLFO.
Loaned specimens: 1 ♀ *Catachlorops (Catachlorops) fuscinevris* (Macquart, 1838); 2 ♀♀ *Catachlorops (C.) leptogaster* Barreto, 1946; 6 ♀♀ *Catachlorops (C.) psolopterus* Wiedemann, 1828; 1 ♀ *Catachlorops (C.) rufescens* Fabricius, 1805; 1 ♀ *Catachlorops (Hadrochlorops) scutellatus*; 23 ♀♀ *Catachhlorops* spp. ATLFO.
Unidentified specimens of Genus *Catachlorops*: 17.

Genus *Chlorotabanus* Lutz, 1913

Chlorotabanus crepuscularis (Bequaert, 1926) – USA: 1 ♀ (1) "30-31-VI-1938 United States │ Florida │ Monticello" (2) "229" (3) "Fairchild col │ Fairchild det 1938". Brazil: 1 ♀ [no date] (1) "[Rio de Janeiro] Itatiaia │J. F. Zikán" [probably misidentified].

Chlorotabanus inanis (Fabricius, 1787) – French Guiana: 1 ♀ (1) “1914 Gourdonville | Museum Paris | Aout, 2758”; 3 ♀♀ [no date] with labels (1) “Guyana Francesa” (2) “2854”, (2) “2855” and (2) “2856”, each one; 1 ♀ (1) “1-VIII-1911 French Guiana | St. Simon Island” | “Nº 11 PROC 558”. Brazil: 1 ♀ (1) “31-VIII-1955 Pará | Belém”; 3 ♀♀ (1) “1/16-XII-1966 Pará | Belém | Utinga”; 1 ♀ [no date] (1) “Pará | Aurá | Belém”; 3 ♀♀ (1) “X-1975 Mato Grosso | Sinop”; 1 ♂ (1) “1975 Mato Grosso | Sinop”; 1 ♀ (1) “XI-1972 Goiás | Jataí”; 1 ♀ (1) “8-II-1918 Minas Gerais | Virginia | Sul de Minas | Faz dos Campos | 1500 m”; 2 ♂♂ (1) “XI-1972 Espírito Santo | Linhares”; 1 ♀ (1) “XII-1931 Rio de Janeiro | Angra dos Reis” (2) “EMBRAPA”; 1 ♀ (1) “18-XII-1928 Rio de Janeiro | Itatiaia | 700 m” (2) “EMBRAPA”; 1 ♀ (1) “10 XII-1940 Rio de Janeiro | Itatiaia | Parque Serra dos Órgãos” (2) “EMBRAPA”; 1 ♀ (1) “9/10-III-1951 Rio de Janeiro | Itatiaia | Macieira | 1830 m”; 3 ♂♂ (1) “1-II-1956 Rio de Janeiro | Petrópolis | Alto Mosela | 1100 m”; 1 ♂ (1) “1-II/8-III-1957 Petrópolis | Le Vallon | Alto Mosela”; 1 ♂ (1) “III-1969 Seropédica | [Antiga] Rod. Rio-São Paulo Km 47”; 1 ♀ (1) “9/10-III-1951 Rio de Janeiro | Itatiaia | Macieira | 1830 m”; 1 ♀ (1) “6/10-XII-1950 Rio de Janeiro | Itatiaia | L41, 1300 m”; 1 ♀ (1) “23-X-1957 Rio de Janeiro | Machado Barros”; 1 ♀ (1) “IV-1941 [Itatiaia] “Parque das Serra dos Órgãos | [Rio] Soberbo”; 1 ♂ (1) “1931 Rio de Janeiro | Rio de Janeiro | Jacarepaguá” (2) “Nº 11 PROC 561”; 1 ♀ (1) ”I-1937 São Paulo | Bananal | Serra da Bocaina”; 1 ♀ (1) “7-II-1902 São Paulo | Santos | Porto do Rei” (2) “Nº 19 PROC 993”; 1 ♀ (1) “28-VI-1941 [no other data] ; 1 ♂ (1) “5-II-1948 [no other data]; 2 ♀ [no label]. ATLFO.

Chlorotabanus mexicanus (Linnaeus, 1758) – USA: 1 ♀ (1) “1914 Billy’s Island | Okefenoke Swamp, Ga [Georgia]” (2) “Nº 11 PROC 559”. French Guiana: 1 ♀ (1) “1914 Guyana Francesa | Gourdonville” (2) Museum Paris | R. Benoist | 2767”. Brazil [probably misidentified]: 1 ♀ (1) “8-II-1918 Minas Gerais | Virginia | Faz. dos Campos | 1500 m”; 1 ♀ (1) “X/XII-1940 Rio de Janeiro | Itatiaia | Parque Nacional da Serra dos Órgãos”; 3 ♀♀ (1) “1-II-1956 Rio de Janeiro | Petrópolis | Alto Mosela, 1100 m”; 1 ♀ (1) “1-II/8-III-1957 Rio de Janeiro | Petrópolis | Le Vallon, Alto Mosélla”. ATLFO.

Chlorotabanus parviceps (Kröber, 1934) – Brazil: 1 ♀ (1) “1940 Pará, Marajó” | “C.E.L.V.A.”; 1 ♀ (1) “IX-X-1944 Espírito Santo | Rib. Engano, Vale | Travassos & N. Santos | ES”.

Unidentified specimens of Genus *Chlorotabanus*: 1.

Genus *Cryptotylus* Lutz, 1913

Cryptotylus unicolor (Wiedemann, 1828) – Brazil: 1 ♀ (1) “II/VI-1961 Amapá | Porto Santana | ICOMI”; 3 ♀♀ (1) “III-1943” (2) “Amazonas | Benjamin Constant”; 2 ♀♀ (1) 2-VI-1958 (2) “Amazonas | Manaus”; 1 ♀ (1) X/XII-1909 Pará | Abeobaça” (2) “Osw 1310”; 1 ♀ (1) “VII-1940 Pará, Belém | Aurá | Mangabeira”; 1 ♀ [no date] (1) “[Pará] Marajó, 907” (2) “Osw 1549”; 6 ♀♀ (1) “1931 Minas Gerais | Paraopeba”; 1 ♀ (1) “1931 Minas Gerais | Paraopeba” (2) “16306”; 1 ♀ (1) “IV-1922 Rio de Janeiro | Campos | Faz. Baronesa” (2) “C.D. Pinto leg” (3) “Osw 1412”; 1 ♂ (21) “5/6-II-1951 Rio de Janeiro | Itatiaia | Estrada Agulhas Negras | km 6, 2000 m”; 1 ♂ (1) ”I-1967 Santa Catarina | Nova Teutônia | 300-500 m” (2) “27°11′S, 52° 23′L”. ATLFO.

Cryptotylus xikrin Gorayeb & Fairchild, 1985 – Brazil: 1 ♀ (1) “31-x/3-XI-1985 Pará | Serra Norte | Arm[adilha] suspensa”.

Genus *Dasybasis* Macquart, 1847

Dasybasis testaceomaculata (Macquart, 1838) – Chile: 2 ♀♀ (1) “II-1970 Concepción | Parque Botânico Hualpen”.

Dasybasis trita (Walker, 1837) as *Dasybasis tritus* – Argentina: 2 ♀♀ (1) ”I-1962 Argentina | Terra del Fuego | Lago Fagnano” (2) “Lane, Coscarón & Capri”.

Dasybasis tritus = *Dasybasis trita* (Walker, 1837).

Unidentified specimens of Genus *Dasybasis*: 2.

Genus *Dasyrhamphis* Enderlein, 1922

Dasyrhamphis ater (Rossi, 1790) as *Atylotus ater* Rossi – [S. Europe, N. Africa]: 1 ♀ [no date] (1) “Grande Atlas [?], H. Immonen, Alluaud, 261” (2) “2898”; 1 ♀ [no date] (1) “2897”.

Dasyrhamphis nigritus (Fabricius, 1794) – Algerie: as *Atylotus alexandrinus* 1 ♀ (1) “5-VI-1914 Algerie | Rocher Blanc” (2) “2878” (3) “J. Surcouf”; 1 ♀ [no date] (1) “Algerie | Rocher Blanc” (2) “2877” (3) “J. Surcouf”; as *Tabanus alexandrinus* 1 ♀ (1) “7-V-1916 Ruiba | 7-5-1916” | “3018”; 2 ♀♀ (no date] (1) “3014” and (1) “3015” each one; 5 ♂♂ (1) “7-V-1916 Ruiba |7-maio-1916” with five labels (2) “3012” (2) “3013” (2) “3016 (2) “3017” (2) “3019”, each one.

Genus *Diachlorus* Osten Sack, 1876

Diachlorus bicinctus (Fabricius, 1805) – French Guiana: 1 ♀ (1) 1919 St Jean du Maroni”. Brazil: 1 ♀ (1) “X-1975 Mato Grosso | Sinpo” (2) Museum Paris | 3005 | *Diachlorus (Diabasis) neivai* SVZ”.

Diachlorus curvipes (Fabricius, 1805) – Brazil: 3 ♀ (1) “X-1975 Mato Grosso | Sinop”.

Diachlorus distinctus Lutz, 1913 – Brazil: 1 ♀ (1) “II-1970 Minas Gerais | Santa Vitória”; 1 ♀ (1) “2-VI-1944 Rio de Janeiro | Angra dos Reis | Japuhiba” (2) ”EMBRAPA”; 3 ♀♀ (1) ”I-1935 Rio de Janeiro | Angra dos Reis | Japuhiba” (2) “EMBRAPA”; 1 ♀ (1) “IX-1934 Rio de Janeiro Angra dos Reis| Jussaral” (2) “EMBRAPA”; 1 ♀ (1) “XI-1931 Rio de Janeiro | Angra dos Reis” (2) “EMBRAPA”; 1 ♀ (1) “III-1922 Rio de Janeiro, Campos” (2) “Osw 1444”; 1 ♀ (1) “1-VI-1949 Rio de Janeiro | Icaraí | Niterói”; 2 ♀♀ (1) “9-XII-1957”, “14-V-1970 Rio de Janeiro, Itaguaí”; 1 ♀ (1) “1-II-1933 Rio de Janeiro | Itatiaia | Est. [Estação] Biológica, 700 m” (2) “EMPRAPA”; 1 ♀ (1) “22-VI-1934 Rio de Janeiro | Itatiaia | Est. [Estação] Biológica, 700 m” (2) “EMPRAPA”; 1 ♀ (1) “IV-1941 Rio de Janeiro | Itatiaia, Soberbo | Serra dos Órgãos”; 1 ♀ (1) “3-III-1944 Rio de Janeiro [Rio de Janeiro), Carmorim”; 6 ♀♀ (1) “10-XI-1938”, “2-V-1937”, “III-1940”, “15-VI-1943”, “10-XII-1937”, “III-1951” Rio de Janeiro | Rio de Janeiro | Deodoro” (2) “EMBRAPA”; 1 ♀ (1) “10-IV-1940 Rio de Janeiro | Rio de Janeiro | Jacarepaguá”; 1 ♀ (1) “28-IV-1940 Rio de Janeiro | Rio de Janeiro | Jacarepaguá | Boca do Mato”; 3 ♀♀ (1) “21-IX-1960 Rio de Janeiro | Rio de Janeiro | Recreio dos Bandeirantes | Lagoa das Tachas”; 1 ♀ (1) “6-V-1951 Rio de Janeiro | Sales”; 2 ♀♀ (1) “20-X-1946”, “10-III-1944” Rio de Janeiro | Seropédica | [Antiga] Est. Rio-São Paulo km 47” (2) “EMBRAPA”; 1 ♀ (1) “6-IX-1954 Rio de Janeiro | Seropédica | [Antiga] Est. Rio-São Paulo, km 47” (2) “EMBRAPA”; 2 ♀♀ (1) “I-1924 Paraná | Rio Negro” (2) “Nº 11 PROC 548” and (2) “Nº 11 PROC 550”, each one; 1 ♀ (1) “2-IV-1936 Hanse”, 1 ♀ (1) “16-II-1948” Hanse”; 6 ♀♀ (1) “2-IV-1936”, “14-IV-1936”, “25-III-1940”, “24-XII-1946”, “9-III-1948”, “21-IV-1948” [no other data]; 1 ♀ (1) “6-V-1935” [no other data]; 1 ♀ 91) “6-V-1936

Nº 02 PROC 003”; 1 ♀ (1) “29-XII-1948” [no other data]; 1 ♀ (1) “3-VI-1949” [no other data]; 1 ♀ (1) “24-II-1949”; 1 ♀ [no date, no procedence] Nº20 PROC 004”; 1 ♀ [no date, no procedence] (1) “Nº 20 PROC 005”. ATLFO.

Diachlorus flavittaenia Lutz, 1913 – Brazil: 2 ♀♀ [no date] (1) “São Paulo, Caraguatatuba” (2) “199” (3) “SP=L”. ATLFO.

Diachlorus fuscistigma Lutz, 1913 – Brazil: 2 ♀♀ (1) “29-VI-1959 Amapá, Rio Felicio” (2) “J. Lane leg”; 1 ♀ (1) “7⁄11-X-1982 Pará | Belém | Floresta APEG” (2) “Arm[adilha]suspensa 1,6 m”.

Diachlorus imaculatus (Wiedemann, 1828) – Brazil: 2 ♀♀ (1) “III-1937 Mato Grosso, Maracajú” (2) “Shannon [trap] | Lane”.

Diachlorus neivai Lutz, 1913 – Brazil: 1 ♀ (1) “X-1954 Mato Grosso | Faz. Primavera” (2) “199”.

Diachlorus nuneztovari Fairchild & Ortiz, 1955 – Brazil: 1 ♀ (1) “29⁄29-V-1992 Pará | Belém | Mocambo” (2) “Arm[adilha] suspensa 1,6 m”.

Diachlorus podagricus (Fabricius, 1805) – Brazil: 1 ♀ (1) “13⁄16-V-1983 (1) “Pará | Belém | Floresta APEG” (2) “Arm[adilha] susp[ensa] 23 m”.

Diachlorus scutellatus (Macquart, 1838) – Brazil: 1 ♀ (1) “7⁄12-VIII-1988 Pará | Belém | Floresta APEG” (2) “Arm[adilha] suspensa 23 m”.

Diachlorus varipes (Rondani, 1848) – Brazil: 1 ♀ (1) “III-1940 Rio de Janeiro | Magé” (2) “194”. ATLFO.

Unidentified specimens of Genus *Diachlorus*: 8.

Genus *Dichelacera* Macquart, 1838

Subgenus *Dichelacera* Macquart, 1838

Dichelacera (Dichelacera) alcicornis Wiedemann, 1828 – Brazil: 1 ♀ (1) “9-X-1912 Espírito Santo | Vale do Leão | Ribeirão do Engano”; 1 ♀ (1) “XI-1919 Rio de Janeiro | Itatiaia | Mont Serrat” (2) “EMBRAPA”; 1 ♀ (1) “25-VI-1931 Rio de Janeiro | Itatiaia 700 m” (2) “EMBRAPA”; 1 ♀ (1) “17-VI-1933 Rio de Janeiro | Itatiaia” (2) “EMBRAPA”; 1 ♀ (1) “25-VI-1933 Rio de Janeiro | Itatiaia, Est. [Estação] Biologica” (2) “EMBRAPA”; 1 ♀ (1) “XII-1933 Rio de Janeiro | Itatiaia” (2) “EMBRAPA”; 1 ♀ (1) “18-XI-1942 Rio de Janeiro | Itatiaia, 700 m” (2) “EMBRAPA”; 1 ♀ (1) “25-XI-1958 [Rio de Janeiro] Itatiaia”; 1 ♀ (1) “II-1924 Rio de Janeiro | Petrópolis | C.[?] Prade” (2) “Nº11⁄697”; 3 ♀♀ (1) “II-1939 Rio de Janeiro | Petrópolis | Rio Ueter” (2) “EMBRAPA”; 1 ♀ (1) “II-1956 Rio de Janeiro | Petrópolis | Alto Mosela, 1100 m”; 1 ♀ (1) “1-II/8-III-1957 Rio de Janeiro | Petrópolis | Le Valllon | Alta da Mosela”; 1 ♀ [no date] (1) “[Rio de Janeiro, Seropédica], [Antiga Estrada] Est. de São Paulo” (2) “Nº 11⁄604”; 2 ♀♀ (1) “I-1937 São Paulo | Bananal | Serra da Bocaina” (2) “EMBRAPA”; 1 ♀ (1) “31-VI-1938 São Paulo | Campos do Jordão | Eng. Lefréve, 1200 m”; 2 ♀♀ (1) “II-1971 São Paulo | Floricultura | Bocaina” (2) “EMBRAPA”; 1 ♀ (1) ”XII-1955 São Paulo | Campos do Jordão”(2) “186” (3) “J. Lane Col”; 2 ♀♀ (1) “II-1971 São Paulo | Floricultura | Bocaina” (2) “EMBRAPA”; 1 ♀ (1) “27-XI-1918 Minas Gerais | Virginia | Faz dos Campos” (2) “Nº11⁄610”; 1 ♀ (1) “23-XI-1943 Minas Gerais | Belo Horizonte | Serra do Cipó”; 309 ♀♀ (1) “I-1970 Minas Gerais [Catas Alta ou Santa Bárbara] Serra do Caraça”; 4 ♀ (1) “I-1924 Paraná | Rio Negro” (2) “Nº11⁄608” (2) “Nº11⁄609” (2) “Nº11⁄610” (2) “Nº11⁄611”, each one; 1 ♀ (1) “IX-1924 Paraná, Rio Negro” (2) “Nº11⁄612”; 1 ♀ [no date] (1) “Paraná | Sul”; 7 ♀♀ (1) “III-1971 all Santa Catarina | Curitibanos”; 1 ♀ (1) “19-XI-1921 EMBRAPA”; 1 ♀ (1) “Nº19⁄999”; 1 ♀ (1) “31-X-1933 [no other data]. ATLFO.

Dichelacera (Dichelacera) amazonensis Henriques, 1995 – Brazil: 1 ♀ PARATYPE (1) “29-x⁄2-XI-1988” Pará | Maraã | Rio Japurá | Maguari” (2) “Arm[adilha] suspensa 20 m”.

Dichelacera (Dichelacera) bifascies Walker, 1848 – Brazil: 4 ♀♀ (1) “I-1935 Maranhão | São Luiz Ribamar” (2) “EMBRAPA”; 1 ♀ (1) “III-1962 Ceará | Ubajara | Serra Ibiapara”; 1 ♀ (1) “IV-1972, Pernambuco | Faz Caruarú, 900 m”.

Dichelacera (Dichechelacera) cervicornis (Fabricius, 1805) – Brazil: 1 ♀ (1) “25-VI-1980 Pará | Benevides | Rod Pará 408 | Km 06”.

Dichelacera (Dichechelacera) damicornis (Fabricius, 1805) – Brazil: 1 ♀ (1) “IV-V-1960 Amapá | Serra do Navio | Bicelli Col”; 1 ♀ (1) “XI-1961 Pará, Belém | F. Bormann Col”; 1 ♀ (1) “24⁄27-X-1981 Pará | Benevides | Rod [Rodovia] Pará 408 Km 06” (2) “Arm[adilha] suspensa 25 m”.

Dichelacera (Dichelacera) januari (Wiedemann, 1819) – Brazil: 83 ♀♀ (1) “IX-1972 Espírito Santo | Linhares” | Alvarenga & Roppa”; 106 ♀♀ (1) “X-1972 Espírito Santo | Linhares | Alvarenga & Roppa”; 24 ♀♀ (1) “XI-1972 Espírito Santo | Linhares | Alvarenga & Roppa”; 3 ♀♀ (1) ”XII-1933 Minas Gerais | Cambuquira” (2) “EMBRAPA”; 1 ♀ (1) “X-1936 Rio de Janeiro | Angra dos Reis”; 1 ♀ (1) “X-1935 Rio de Janeiro | Angra dos Reis | Japuhiba”; 1 ♀ (1) “X-1935 Rio de Janeiro | Angra dos Reis | Jussaral”; 1 ♀ (1) “X-1934 Rio de Janeiro | Angra dos Reis | Jussaral | L. Travassos Col”; 1 ♀ (1) “10-IX-1940 Rio de Janeiro | Duque de Caxias | Petrobrás”; 2 ♀♀ (1) “II-1932 Rio de Janeiro | Friburgo” (2) “Nº 16300” (2) “16340”, each one; 2 ♀♀ (1) “22-XII-1933”, 1 ♀ (1) “19-VI-1934”, 4 ♀♀ (1) “19-VI-1934”, 1 ♀ (1) “28-III-1937” Rio de Janeiro | Itatiaia, 1300 m” (2) “EMBRAPA”; 1 ♀ (1) ”XII-1922 Rio de Janeiro | Itatiaia”; 1 ♀ (1) “18-XII-1931 Rio de Janeiro | Itatiaia, 700 m” (2) “EMBRAPA”; 1 ♀ “13-VI-1937 Rio de Janeiro | Itatiaia | Est. [Estação] Biologica, 1100 m, Zirkán” (2) “EMBRAPA”; 1 ♀ (1) “3/8-II-1951 Rio de Janeiro | Itatiaia, L 41 | 1300 m”; 2 ♀♀ (1) “9/10-III-1951 Rio de Janeiro | Itatiaia | Macieira | 1830 m”; 1 ♀ (1) “16-VI-1953 Rio de Janeiro | Itatiaia | Maromba, 1150 m”; 1 ♀ (1) “XI-1902 Rio de Janeiro [Magé], Mauá” (2) “Nº 20/000”; 5 ♀♀ (1) “24-I/23-II-1958 Rio de Janeiro | Petrópolis”; 1 ♀ (1) “9-II-1971 Rio de Janeiro | Petrópolis”; 3 ♀ (1) “XI-1931” Rio de Janeiro | Rio de Janeiro” (2) “EMBRAPA”; 1 ♀ (1) “XI-1931”, 3 ♀♀ (1) “15-IX-1965” Rio de Janeiro | Rio de Janeiro | Corcovado” (2) “EMBRAPA”; 1 ♀ (1) “XI-1931 Rio de Janeiro | Rio de Janeiro | Corcovado”; 1 ♀ (1) “I-1934 Rio de Janeiro | Rio de Janeiro, Corcovado” (2) “Inst 10029” [no head]; 1 ♀ (1) “15-IX-1943 Rio de Janeiro | Rio de Janeiro | Tijuca”; 1 ♀ (1) “II-1969 Rio de Janeiro | Teresópolis”; 1 ♀ (1) ”XII-1933 São Paulo | Bananal | Serra da Bocaina” (2) “EMBRAPA”; 1 ♀ (1) “21-VI-1938 São Paulo | Campos do Jordão”; 1 ♀ (1) “I-1967 São Paulo | Salesópolis | Est. [Estação] Biológica | Boraceia, 850 m” (2) “EMBRAPA”; 3 ♀♀ (1) “1924 Paraná | Rio Negro” (2) “Nº 11/617”, (2) “Nº11/618”, (2) “Nº 11/619”, each one; 2 ♀♀ (1) “II-1971 Santa Catarina | Curitibanos”**;** 17 ♀♀ (1) “VII-1971 Santa Catarina | Curitibanos”; 1 ♀ (1) “VI-1957 Santa Catarina | J. Lane Col”; 1 ♀ [no date] (1) “EMPRAPA”; 2 ♀♀ (1) “28-XII-1947”, 1 ♀ (1) “6-XII-1948” [no other data]; 2 ♀♀ (1) “23-VI-1948” [no other data]; 1 ♀ (1) “17-VI-1949” [no other data]; 1 ♀ (1) “4-II-1949” [no other data]; 1 ♀ [no date] (1) “Museu Nacional”; 1 ♀ (1) [no date] “Nº 11/614” (2) “Museu Nacional”. ATLFO.

Dichelacera (Dichechelacera) marginata (Macquart, 1847) – Brazil: 1 ♀ (1) “6-V-1982 Pará | Benevides | Rod [Rodovia] Pará 408, Km 06”.

Dichelacera (Dichelacera) scutellata (Williston, 1895) – Bolivia: 31 ♀♀ (1) "2-II-1955 Naranjos" (2) "IOC"; 5 ♀♀ (1) "1955 El Carmem" (2) "IOC". Brazil: 1 ♀ (1) "XII-1929 Mato Grosso | Faz Murtinho"; 1 ♀ (1) " I-1954 Mato Grosso | Arapuã" (2) "IOC"; 3 ♀♀ (1) "1940 Mato Grosso | B. Tapirapé"; 1 ♀ (1) "I-1941 Mato Grosso | Salobra" (2) "COM.I.O.C." ATLFO.

Dichelacera (Dichelacera) varia Wiedemann, 1828 – Brazil: 1 ♀ (1) "1958 Amapá | Mazagão | V. Nova" (2) "191" (3) "Damaceno".

Unidentified specimens of Genus *Dichelacera*: 47.

Genus *Dicladocera* Lutz, 1913

Dicladocera guttipennis (Wiedemann, 1828) – Brazil: 1 ♀ (1) "3-IX-1919 Minas Gerais | Virginia | Faz dos Campos, 1500 m" (2) "Nº11/625; 3 ♀♀ (1) "5-VI-1910 Rio de Janeiro | Serra de Angra dos Reis" (2) "Osw 1304 | RJ", (2) "Osw 1515" and (2) "Osw 1516", each one; 1 ♀ (1) "5-VI-1910 Rio de Janeiro | Angra dos Reis"; 1 ♀ (1) "XI-1934 Rio de Janeiro | Angra dos Reis | Jussaral" (2) "EMBRAPA"; 1 ♀ (1) "12-VIII-1930 Rio de Janeiro | Itatiaia, 700 m" (2) "EMBRAPA"; 1 ♀ (1) "3-IX-1935 Rio de Janeiro | Itatiaia, 816 m"; 1 ♀ (1) "14-IX-1942 Rio de Janeiro | Itatiaia, 700 m" (2) "EMBRAPA"; 1 ♀ (1) "25-VIII-1946 Rio de Janeiro | Itatiaia, 900 m"; 1 ♀ (1) "VIII-1925 Paraná | Rio Negro | Franciscanos" (2) "Nº 11/587"; 3 ♀♀ (1) "17-VIII-1948", "21-VIII-1948", "4-IX-1948" Hense Fest"; 4 ♀♀ [no data]; [2 ♀♀ loaned]. ATLFO.

Dicladocera macula (Macquart, 1846) – Brazil: 1 ♀ (1) "5-VI-1910 São Paulo | Bonito" (2) "Osw 1303". ATLFO.

Genus *Erioneura* Barretto, 1950

Erioneura fuscipennis (Wiedemann, 1828) – Brazil: 1 ♀ (1) "15-XII-1925 Rio de Janeiro | Itatiaia" (2) "EMBRAPA"; 1 ♀ (1) "XII-1933 Rio de Janeiro | Itatiaia | Est [Estrada] Cunha, 800 m"; 1 ♀ (1) "III-1942 Rio de Janeiro (2) Itatiaia | Faz [|Fazenda] Penedo"; 1 ♀ (1) "II-1954 São Paulo | Bananal" (2) "Serra da Bocaina | Parque de Criação de Trutas"; 4 ♀♀ (1) "1-III-1933", "28-VI-1941", "31-VI-1947", "26-III-1933" [no other data]. ATLFO.

Genus *Lepiselaga* Macquart, 1838

Subgenus *Conoposelaga* Barretto, 1949

Lepiselaga (Conoposelaga) aberrans Lutz, 1913 – Brazil: 1 ♀ (1) "II-1934 São Paulo | Sertãozinho". ATLFO.

Subgenus *Lepiselaga* Macquart, 1838

Lepiselaga (Lepiselaga) crassipes (Fabricius, 1805) – Venezuela: 3 ♀♀ (1) "1925 Guarico | La Cruz | Ruviera" (2) "Museum Paris | Venezuela | Etat de Guarico | La Cruz Ruviera (3) "M. Crisol, 1925, Decémber". Brazil: 1 ♀ (1) "2-V-1961 Amapá | Mazagão | Rio Puxacá"; 1 ♀ (1) "V-1934 Amazonas | Tabatinga"; 1 ♀ (1) "17-XI-1955 Amazonas | Manaus"; 1 ♀ (1) "17-VI-1955 Amazonas | Manaus (2) "D.Z. 9/995"; 5 ♀♀ (1) "29-VI-1957 Amazonas | Manaus" (2) "D.Z. 9/995"; 4 ♀♀ (1) "4-X-1953", 14 ♀♀ (1) "21-V-1955", 1 ♀ (1) "VI-1955", 1 ♀ (1) "X-1957", 1 ♀ (1) "4-V-1957", 1 ♀ (1) "11-X-1957", 1 ♀ (1) "23-XI-1958" Amazonas | Manaus" (2) "D.Z. 9/995"; 1 ♀ (1) "22-VIII-1955 Pará | Belém"; 1 ♀ (1) "VII-1952 Pará | Belém Rio Paru"; 3 ♀♀ (1) "31-VIII-1955 Pará | Belém" (2) "D.Z. 9/995"; 2 ♀♀ [no date] (1) "Mato Grosso | Barra do Bugres | Passareli"; 4 ♀♀ (1) "III-1940 Mato Grosso | Salobra | Com. Inst. O. Cruz"; 1 ♀ [no date] (1) "Mato Grosso" (2) "932" (3) "EMBRAPA"; 1 ♀ (1) "15-II-1939 Minas Gerais | Calado | Rio Doce" (2) "Martins & Lopes"; 2 ♀ (1) "III-1922 [Rio de Janeiro] Campos" | C. Pinto Col (2) "Osw 1456"; 1 ♀ (1) "20-X-1945 Rio de Janeiro | Seropédica [Antiga] | Est. [Estrada] Rio São Paulo, Km 47" (2) "EMBRAPA"; 1 ♀ (1) "26-II-1940 São Paulo | Ilha Seca" | Com. Inst. O. Cruz"; 1 ♀ (1) "XI-1941 Paraná | Porto São Pedro".

Genus *Leucotabanus* Lutz, 1913

Leucotabanus albicans Macquart = *Leucotabanus exaestuans* (Linnaeus, 1758).

Leucotabanus albovarius (Walker, 1854) – Brazil: 1 ♀ [no date] (1) "Amazonas, Manaus".

Leucotabanus exaestuans (Linnaeus, 1758) – Brazil: 1 ♀ (1) "2-IV-1961 Amapá | Serra do Navio | ICOMI"; 1 ♀ (1) "VIII-1969 Pará | Belém | Paricatuba"; 145 ♀♀ (1) "XI-1972 Goiás, Jataí"; as *Leucotabanus leucaspis* Wiedemann, 1828 – 1 ♀ [no date] (1) "Goiás | Campinas" (2) "EMBRAPA"; 1 ♀ (1) "X-1975 Mato Grosso | Sinop"; 1 ♀ (1) "IX-1972", 1 ♀ (1) "X-1972", 1 ♀ (1) "XII-1972 Espírito Santo | Linhares"; 1 ♀ (1) "1923 Chapada Jovem[?]"; 1 ♀ (1) "XI-1932 Rio de Janeiro | Angra dos Reis"(2) "Osw 1577"; 1 ♀ (1) "I-1933 Rio de Janeiro | Angra dos Reis"; 1 ♀ (1) "10/12-X-1950 [Rio de Janeiro] Itatiaia | L 412 | 1300 m" (2) "Trav. Albuquerque & Pearson"; 1 ♀ [no date] (1) "[Rio de Janeiro] Teresópolis | Travassos & Freitas | RJ"; 1 ♀ [no date] (1) "São Paulo | Vera Cruz | H. Ramalho Col"; 1 ♀ [with two garbled labels]. ATLFO.

Leucotatanus flavinotum (Kröber, 1934) – Brazil: 1 ♂ (1) "9-X-1943 Amazonas | Borba | lago Araxá".

Leucotabanus pauculus Fairchild, 1951 – Brazil: 4 ♀♀ (1) "2-IV-1961 Amapá | Serra do Navio | ICOMI".

Genus *Phaeotabanus* Lutz, 1913

Phaeotabanus aphanopterus (Wiedemann, 1828) – Brazil: 1 ♀ (1) "XI-1972 Goiás | Jataí"; 1 ♀ 1932 (1) "Rio de Janeiro | Angra dos Reis"; as *Phaeotabanus aphanoptera* – 1 ♀ [no date] (1) "São Paulo | Juquiá" (2) "1138" (3) "234". ATLFO.

Phaeotabanus cajennensis (Fabricius, 1787) – French Guiane: 3 ♀♀ (1) "1914 Charvei" (2) "Charvei | Guyane Française | R. Besnoit | Museum Paris" and (3) "2877", (3) "2880", (3) "2881", each one (4) "Decémber" [all 3 specimens]. Brazil: 1 ♀ (1) "8-VI-1954 Amapá | F. Primavera" (2) "Rabelo Col"; 1 ♀ (1) "IX-1957 Amapá | Porto Platon | Santana" (2) "212" (3) "K. Lenko leg"; 1 ♀ (1) "12-XII-1955", 1 ♀ (1) "3-IV-1956", 22 ♀♀ (1) "11-VI-1958 Amazonas, Manaus" (2) "D.Z. 9/59; 1 ♀ (1) "X-1975 Mato Grosso | Sinop".

Phaeotabanus fervens (Linnaeus, 1758) – Brazil: 2 ♀♀ (1) "11-X-1957 Amapá | Serra do Navio" (2) "237"; 1 ♀ (1) "10/13-VIII-1992 Pará | Santana do Araguaia" (2) "Arm[adilha] Malaise".

Phaeotabanus limpidapex (Wiedemann, 1828) – Brazil: 1 ♀ (1) "I-1972 Minas Gerais | Serra do Caraça"; 1 ♀ (1) "1932 Rio de Janeiro | Angra dos Reis" (2) "Osw 1524"; 1 ♀ (1) "1-X-1932 Rio de Janeiro | Angra dos Reis"; 2 ♀♀ (1) "23-VI-1931 Rio de Janeiro | Itatiaia, 700 m" (2) "EMBRAPA"; 1 ♀ (1) "I-1944 Rio de Janeiro | Itatiaia"; 1 ♀ (1) "1-II-1956 Rio de Janeiro | Petrópolis | Alto Mosela, 1100 m"; 1 ♀ [no date] (1) "Rio de Janeiro | Itatiaia" (2) "Nº 11/007" | "Diptera Ins Oswaldo Cruz"; 3 ♀♀ (1) "I-1944", "XI-1966", "I-1967 Malaise trap" [no other data]; 4 ♀♀ (1) "XII-1969", 3 ♀♀ (1) "I-1972", 3 ♀ (1)

“I-1972”, 1 ♀ (1) “III-1976 Rio de Janeiro | Rio de Janeiro | Represa do Rio Grande”; 1 ♀ (1) “1933 Rio de Janeiro | Rio de Janeiro | Tijuca” (2) “EMRAPA”; 1 ♀ (1) “2-XI-1938 São Paulo | Jundiaí” (2) “1111” (3) “SP” (4) “232”; 1 ♀ (1) “29-VI-1976” [no other data]. ATLFO.

Phaeotabanus litigiosus (Walker, 1850) – Brazil: 1 ♀ (1) “V-1972 Espírito Santo | Linhares”; 3 ♀♀ (1) “I-1935 Rio de Janeiro | Angra dos Reis | Japuhiba” (2) “EMBRAPA”; 1 ♀ (1) “II-1931 Rio de Janeiro | Angra dos Reis” (2) “EMBRAPA”; 1 ♀ (1) “III-1940 Rio de Janeiro | Magé” (2) “Serviço Febre Amarela | M.E.S. Bra. | RJ”; 8 ♀♀ (1) “4/5-XII-2013” Rio de Janeiro | Mangaratiba | Ilha da Marambaia”; 1 ♀ (21) “7-II-1902 São Paulo | Santos | Porto do Rei” (2) “Nº 9/994”; 1 ♀ (1) ”XII-1940 Osw 1464”; 1 ♀ (1) “II-1931 Osw 1464”; 1 ♀ (1) “I-1932 Osw 1461”; 1 ♀ (1) “I-1932 EMBRAPA”; 2 ♀♀ (1) “XII-1932 Osw 1573” and (1) “XII-1932 Osw 1572”, each one. ATLFO.

Phaeotabanus prasinventris (Kröber, 1929) – Brazil: 1 ♀ (1) “31-VI-1959 Amapá | Rio Feliçio” | (2) “236”.

Genus *Philipotabanus* Fairchild, 1943

Subgenus *Philipotabanus* Fairchild, 1943

Philipotabanus (Philipotabanus) stigmaticalis Kröber, 1931 – Brazil: 1 ♀ (1) “3⁄7-X-1988 Amazonas | Marãa | Rio Japurá | Maguari” (2) “Arm[adilha] susp[ensa] 20 m”.

Genus *Pseudacanthocera* Lutz & Neiva, 1914

Pseudacanthocera brevicornis (Enderlein, 1925) – Bolivia: 7 ♀♀ (1) “II-1955 El Carmem” | Comissão I.O. Cruz”; 3 ♀♀ 2-II-1955 (1) “Naranjos | C.I.O. Cruz”.

Pseudacanthocera parallelifrons Kröber, 1929 – Brazil: 1 ♀ (1) “14-XII-1955 São Paulo | Ilha de Santo Amaro” (2) “Forattini | 177” (3) “SP=L”. ATLFO.

Pseudacanthocera sylveirii (Macquart, 1838) – Brazil: 1 ♀ (1) “XII-1932”, 1 ♀ (1) “I-1932” Rio de Janeiro | Angra dos Reis” (2) “EMBRAPA”; 1 ♀ (1) “16-II-1925 Rio de Janeiro | Itatiaia, 700 m” (2) “EMBRAPA”; 1 ♀ (1) “XII-1938 São Paulo | Juquiá” (2) “SP” (3) “278” (4) “1130”. ATLFO.

Genus *Rhabdotylus* Lutz, 1913

Rhabdotylus planiventris (Wiedemann, 1828) as *Stibasoma planiventre* – Brazil: 1 ♀ (1) “IX-1969 Pernambuco | Recife | Horto 2 Irmãos”; 1 ♀ (1) “12-II-1937 Rio de Janeiro | Angra dos Reis | Jussaral | RJ”; 1 ♀ (1) “24-XII-1923 Rio de Janeiro | Itatiaia, 700 m” (2) “EMBRAPA”; 1 ♀ (1) “9/10-III-1951 Rio de Janeiro | Itatiaia | Macieira [Abrigo Macieiras], 1830 m”; 2 ♀♀ (1) “XI-1959 Rio de Janeiro | Itatiaia”; 1 ♀ (1) “II-1937 “Paraná | Paranaguá” (2) Fairchild Col | Fairchild Det” (3) “1838” ; 1 ♀ (1) “17-VI-1936 Poço Preto”; 1 ♀ (1) “12-VI-1935 [no other data]; 1 ♀ (1) “20-VI-1948 [no other data]. ATLFO.

Rhabdodotylus viridiventris (Macquart, 1838) as *Stibasoma viridiventre* – Brazil: 1 ♀ (1) “XII-1932 Rio de Janeiro | Angra dos Reis” (2) “RJ”; 1 ♀ [no date] (1) “Osw 1453”. ATLFO.

Genus *Selasoma* Macquart, 1838

Selasoma tibiale (Fabricius, 1805) – Brazil: 1 ♀ (1) “VII-1952 Pará | Rio Paru”; 1 ♀ (1) “V-1969 Ceará | Barbalha”; 1 ♀ (1) “III-1940 Mato Grosso | Salobra” (2) “Com. Inst. O. Cruz”; 1 ♀ [no date] (1) “Minas Gerais | Jaguará” (2) “Museu Nacional 11/553”; 1 ♀ [no date] (1) “Museu Nacional | *Selasoma tibiale*” (2) “ Nº 11/559”; 1 ♀ (1) “6-VI-1934 Rio de Janeiro | Leopoldo Bulhões” (2) “EMBRAPA”; 2 ♀♀ [no date] (1) “Ins Osw Cruz”. ATLFO.

Genus *Stibasoma* Schiner, 1867

Stibasoma bicolor Bigot, 1892 – Brazil: 1 ♀ (1) “6-XII-1925 Rio de Janeiro | Itatiaia | Est. [Estação] Biológica, 900 m” (2) “EMBRAPA”. ATLFO.

Stibasoma currani Philip, 1943 – Brazil: 1 ♀ (1) “XI-1934 Juarete Parko[?]”; 2 ♀♀ (1) “XI-1959 Rio de Janeiro | Itatiaia”. ATLFO.

Stibasoma planiventre = *Rhabdotylus planiventris* (Wiedemann, 1828)

Stibasoma theotaenia (Wiedemann, 1828) – Brazil: 1 ♀ (1) “III-1946 Rio de Janeiro | Angra dos Reis | Japuhiba” | Trav.”; 1 ♀ (1) “I-1933 Rio de Janeiro | Rio [de Janeiro] Represa Carmorim” (2) “H. Souza Lopes Col” (3) “Osw 1565”; 1 ♀ (1) “9-X-1942 Espírito Santo | Vale do Itauna | Ribeirão do Engano”; 1 ♀ (1) “I-1963 Espírito Santo | Linhares | Parque Soaretama” (2) “Coleção Campos Seabra”. ATLFO.

Stibasoma viridiventre = *Rhabdodotylus viridiventris* (Macquart, 1838)

Stibasoma willistoni Lutz, 1907 – Brazil: 1 ♀ (1) “XII-1931 Rio de Janeiro | Angra dos Reis” (2) “Osw 1554”; 1 ♀ (1) “XI-1932 [Rio de Janeiro] “Angra dos Reis” (2) “Osw 1561”; 2 ♀♀ (1) “I-1935 Rio de Janeiro | Angra dos Reis | Japuhiba” (2) “EMBRAPA”; 1 ♀ (1) “1938 Rio de Janeiro [Rio de Janeiro], DF”(2) “184 | RJ”; 1 ♀ (1) “II-1951 Rio de Janeiro [Rio de Janeiro], Floresta da Tijuca, DF”(2) “Coleção Campos Seabra” (3) “RJ=S”; 1 ♀ [no date] (1) “Rio de Janeiro | Rio de Janeiro | Paineiras | Corcovado”. ATLFO.

Genus *Stenotabanus* Lutz, 1913

Subgenus *Stenochlorops* Fairchild, 1969

Stenotabanus (*Stenochlorops) bequaerti* Rafael, Fairchild & Gorayeb, 1982 – Brazil: 1 ♀ (1) “18-VIII-1955 Amazonas | Manaus” (2) “DZ 9/59”.

Unidentified specimens of Genus *Stenotabanus*: 5.

Genus *Stictotabanus* Lutz & Neiva, 1914

Stictotabanus nomem nuden is now synonimized to *Stypommisa* Enderlein, 1914.

Stictotabanus conspicuous in Lutz, Araujo & Fonseca, 1918 – Brazil: 1 (?), Itaiaia RJ, 12-9-1931 [with no head]. This is an unrecognizable *nomem nuden* with no description.

Genus *Stigmatophtalmus* Lutz, 1913

Stigmatophtalmus altivagus Lutz, 1913 – Brazil: 1 ♀ (1) “16-X-1925 Rio de Janeiro | Itatiaia | Colação” (2) “J.F. Zikán | Barreto det.” (3) “Nº 11.114 (4) “Diptera | Ins. Oswaldo Cruz”; 1 ♀ (1) “2-II-1921 Rio de Janeiro | Itatiaia | Mont Serrat” (2) “Bruno Lobo Col (3) “Nº PROC 11555”; 1 ♀ (1) “20-XI-1926 Rio de Janeiro | Itatiaia 700 m” (2) “W. Zirkán” (3) “EMBRAPA”; 1 ♀ (1) “15-II-1972 Rio de Janeiro | Petrópolis | Alto Mosella” (2) “D.O. Albuquerque”. ATLFO.

Genus *Stypommisa* Enderlein, 1923

S*typommisa affinis* Kröber, 1929 – Brazil: 1 ♀ (1) “VIII-1945 São Paulo | Cantareira” (2) “240” (3) “Barreto Col”. ATLFO.

Stypommisa apicalis Fairchild & Wilkerson, 1986 – Brazil: 6 ♀♀ (1) “1971/1673 (1) “Rondonia | Vilhena, 500 m”.

Stypommisa aripuana Fairchild & Wilkerson, 1986 – Brazil: 1 ♀ (1) “10⁄13-VIII-1984 Pará | Serra Norte | nº 1 Canga” (2) “Arm[adilha] susp[ensa] 1,6 m”.

Stypommisa captiroptera (Kröber, 1930) – Brazil: 1 ♀ (1) “27⁄29-VI-1988 Pará | Benevides | Faz Morelândia” (2) “Arm[adilha] susp[ensa] 1,6 m”.

Stypommisa glandicolor Lutz, 1912 – Brazil: 1 ♀ (1) “5⁄7-IX-1983 Pará | Serra Norte | Est[rada] Manganês” (2) “Arm[adilha] Malaise”.

Stypommisa modica Hine, 1920 – Brazil: 1 ♀ (1) “4⁄6-XI-1983 Pará | Serra Norte | Est[rada] Manganês” (2) “Arm[adilha] susp[ensa] 23 m”.

Stypommisa prunicolor (Lutz, 1912) – Brazil: 1 ♀ (1) “11-1973 Rondonia | Vilhena, 500 m”.

Unidentified specimens of Genus *Stypommisa*: 556.

Tribe Heamatopotini Bequaert, 1930

Genus *Chrysozona* Meigen, 1800 = Genus *Haematopota* Meigen, 1803

Chrysozoma alluaudi Scf. = *Hematopota alluaudi* Surcouf, 1908.

Chrysozona decora = *Haematopota decora* Walker, 1850.

Chrysozona italica Meigen = *Haematopota italica* Meigen, 1804.

Chrysozona longicornis Macquart = *Chrysops longicornis* Macquart, 1838.

Chrysozona pluvialis = *Haematopota pluvialis* (Linnaeus, 1761).

Chrysozona rufula = *Haematopota rufula* (Surcouf, 1909).

Chrysozona vittata Lowe = *Haematopota vittata* Loew, 1858.

Chrysozona vulnerans Scopoli = *Haematopota vulnerans* (Surcouf, 1909).

Genus *Euancala* Enderlein, 1922

Euancala maculatissima (Macquart, 1838) as *Tabanus maculatissima* – Mozambique: 2 ♀♀ (1) “XII-1928/I-1929” Amatongas” (2) “Museum Paris | Moçambique | Nov Chupanga | December-Janvier 1929 | J. Surcouf” (2) “2818” and (2) “2819”.

Genus *Haematopota* Meigen, 1803

Haematopota albihirta Karsch 1887 = *Haematopota mactans*, Austen 1908 = *Chrysops mactans* Austen, 1908 – Somalia: 2 ♀♀ (1) “VI-1901 Museum Paris | Lif du Dakato | Somali S. Herrar | E. Brumpt, 1906” (2) “*Haematopota mactans*, Austen | E.E. Austen | 21-VI-1908” (3) “2887” and (3) “2890” each one.

Haematopota alluaudi Surcouf, 1908 as *Chrysozoma alluaudi* Scf. – Kenia: 2 ♀♀ (1) “I-1912 Afrique or. Anglaise | Mt. Kenya, Vert. Ouest | Zone des Forêts | Alluaud & Jeannel” (2) “Forêts Moyennes | Bambous Infer. | 2400-2800 m, janv. 1912 St. 40” (3) “2899” and (3) “2900”, each specimen.

Haematopota cingulata Wiedemann, 1828 as *Hippocentrum cingulata* Wiedemann – [East Asia] 1 ♀ [no date, no procedence] (1) “Museum Paris | Coll J. Surcouf, 191[?]” (2) “2852”.

Haematopota cordigera Bigot, 1891 as *Chrysops cordigera* Bigot – Cameron: 2 ♀♀ [no date] both with labels (1) “Cameron, Kribi | *Chrysozona cordigera* Bigo.” (2) “2882” and (2) “2885”, each one.

Haematopota decora Walker, 1850 as *Chrysozona decora* – Mozambique: 2 ♀♀ (1) “XII-1928/I-1929 Museum Paris | Moçambique | Nov Chupanga | J. Surcouf” (2) “2882” and (2) “2883”, each one.

Haematopota italica Meigen, 1804 as *Chrysozona italica* Meigen – France: 1 ♀ [no date] (1) “La Celle Dunoise” (2) “2909” [without wings]; 1 ♀ 19[?] (1) “Ardennes | Vendresse” (2) “Museum Paris | Vendresse [Ardennes] | R. Benoist, 19[?]” (3) “2970”.

Haematopota pluvialis (Linnaeus, 1761) as *Chrysozona pluvialis* – Canada: 1 ♀ (1) “09/10-VI-1922 Bois N. Dame” [Notre-Dame-de-Bois, Quebec] | F. Le Cerf” (2) “Museum Paris | 2905”; 2 ♀♀ (1) “14-VI-1923 Nemours” (2) “Museum Paris | J. Surcouf, 1919” and (3) “2903” and (3) “2094”, each one; 1 ♀ [no data, no antennae].

Haematopota pungens Doleschall, 1856 as *Tabanus punges* – Laos: 1 ♀ (1) “14-IV-1918 Laos | Nam Tian [?] | R. Vitalis de Salvaza” (2) “2836”; 1 ♀ (1) “24-IV-1918 Laos | Ham Lang | R. Vitalis de Salvaza” (2) “3000”.

Haematopota rufula (Surcouf, 1909) as *Chrysozona rufula* – Central African Republic – 1 ♀ [no date] (1) “Haut Sangha” (2) “2871”.

Haematopota vittata Loew, 1858 as *Chrysozona vittata* Lowe – Mozambique: 2 ♀♀ (1) “XII-1928/I-1929 Museum Paris | Moçambique | Nov Chupanga | J. Surcouf” (2) “2901” and (2) “1902”, each one.

Haematopota vulnerans (Surcouf, 1909) as *Chrysozona vulnerans* Scopoli – Kenia: 1 ♀ (1) “1932/33 Kenia | Mais Forest Kinengop | Mte. Aberdare | Vers’ Ouest, 2600 m” (2) “Museum Paris | Mission de l’Ommo | C. Arambourg | P.A. Chappuis & R. Jeanne” (3) “2999”.

Geuns *Heptatoma* Meigen, 1803

Heptatoma pellucens (Fabricius, 1776) – [Europe, Asia] 1 ♀ (1) “13-VI-1927 Frankaf. Od. | M.P. Riedel” (2) “*Heptatoma (Hexatoma) pellucens* Fbr. | Riedel det.” (2) “EMBRAPA”.

Genus *Hippocentrum* Austen, 1908

Hippocentrum cingulata Wiedemann = *Haematopota cingulata* Wiedemann, 1828.

Hippocentrum versicolor Austen, 1908 – Ivory Coast: 1 ♀ (1) “1910 Museum Paris | Cote d’Ivoire | A. Chevalier” (2) “2847”; 1 ♀ (1) “1919 Museum Paris | Coll Surcouf” (2) “3002”.

Tribe Tabanini Latreille, 1802

Genus *Ancala* Enderlein, 1922

Ancala fasciata (Fabricius, 1775) as *Tabanus atripes* [Van der] Wulp – Gabon: 1 ♀ (1) “1912 (1) “ Museum Paris, Ogooué | Lambaréné | R. Ellenberger, 1912” | 2784”.

Genus *Atylotus* Osten Sacken, 1875

Atylotus alexandrinus Wied. = *Dasyrhamphis nigritus* (Fabricius, 1794).

Atylotus anthracinus (Meigen, 1820) – Morocco: 1 ♀ (1) “1919 Museu Paris | Maroc | Ain Leuh, 1350 m | klau s. de Meknés | R. Benoist” (2) “2893”; 1 ♀ [no date] (1) “Museu Paris | Maroc | Rabat” (2) “2892”.

Atylotus ater Rossi = *Dasyrhamphis ater* (Rossi, 1790).

Atylotus barbarus Coquillet [in error, the species appears in Brauer (1880), as *Atylotus barbarus* Coquebert, 1799, and as *Tabanus barbarus* in Kertész (1900)] = *Tabanus barbarus* Coquebert, 1804.

Atylotus bifarius Loew = *Tabanus bifarius* Lowe, 1858.

Atylotus clutilfluris Macquart [Unidentified name] – Argelia: 1 ♀ (1) V-VI-1911 Algerie, Rouiba, J. Surcouf 1913”.

Atylotus fulvus (Meigen, 1820) as *Ochrops fulvus* – Italia: 1 ♀ [no date] (1) “Bruke Canal | pré [illegible]” | (2) “EMBRAPA”; as *Tabanus fulvus* – 1 ♀ (1) “Les Hes. Brittes, 8-7-1902” | “2797”.

Atylotus gigas Macquart, 1834 – Argelia: 1 ♀ [no date] (1) "Zuyrich [?]" (2) "EMBRAPA" (3) "G. Bouvier" [without right wing]; 1 ♀ [no date, no procedence] (1) "Museu Paris | G. A. Poujade Coll" (2) "2963".

Atylotus lunatus Fab. = *Tabanus lunatus* Fabricius, 1794.

Atylotus nemoralis Meigen, 1820 – Argelia: 2 ♀♀ (1) "V/VI-11911 Algerie | Rouiba | J. Surcouf" (2) "2936" and (2) "2934", each one; 1 ♀ "19[??] Museum Paris | Rombouillet (Sseine-&-Oise) | E. Séguy" (2) "2962".

Atylotus quatuornotatus Meigen, 1820 – France: 1 ♀ (1) "VIII-1909 Bleymard Achalme" (2) "2950"; 1 ♀ (1) "1-VI-1911 "[France, Le] Bleymard" (2) "2949".

Atylotus thoracicus Hine, 1900 – USA: 1 ♀ (1) "8-VI-1940 New York | McLean J. N. Belkin" | (2) "J. N. Belkin Det 194[?]".

Genus *Hybomitra* Enderlein, 1922

Hybomitra aequetincta (Becker, 1900) as *Hybomitra aequentictus* – Canada: 1 ♀ (1) "5-VI-1948 Knob Lake | 54°57′, 66°47′ | R.G. Munroe"; 1 ♀ (1) "16-VI-1954 Que. [Quebec], Indian House L." (2) "R. Coyles".

Hybomitra affinis (Kirby, 1837) – Canada: 1 ♀ (1) "26-VI-1948 Y.T. [Yukon Territory], Watson Lakle" (2) "M.T. Hughes"; 1 ♀ (1) "19-VI-1953 Man. [Manitoba], Carberry" (2) "Brooks & Kelton"; *as Therioplectes affinis* Kirby – 1 ♀ (1) "1911 Museum Paris | Colombie Britaniq | du cote de Territoire du Yukon | region du Lac Teslim | T. Obalski 1911" (2) "2886".

Hybomitra arpadi (Szilady, 1923) – Canada: 1 ♀ (1) "21-VI-1960 "Y.T. [Yukon Territory], La Force | 132°20′, 62° 41′, 3300" (2) "J.E.H. Martin".

Hybomitra astute (Osten-Sacken, 1876) as *Hybomitra astutus* – Canada: 1 ♀ (1) "10-VI-1960 "Y.T. [Yukon Territory], La Force | 132°20′, 62°41′, 3300" (2) "E.W. Rockburne"; 1 ♀ (1) "8-VI-1954 Que. [Quebec], Indian House L." (2) "R. Coyles".

Hybomitra aterrima (Meigen, 1820) as *Tabanus aterrimus* – France: 1 ♀ (1) "1-VIII-1923 St. Veran | H'-A', 2000-2400 m | R. Benoist" (2) "2981". Austria: as *Tabanus aterrimus* var. *auripes* – 1 ♀ [no date] (1) "Namlos | Tirol" (2) "2780".

Hybomitra atrobasis (Mc Dunnough, 1921) – Canada: 1 ♀ (1) "14-VI-1935 B.C. [British Columbia], Plateau Trail" (2) "J.D. Gregson".

Hybomitra borealis (Fabricius, 1781) – [Europe, Asia]: 1 ♀ [no data, destroyed, only thorax].

Hybomitra brevis (Lowe, 1858) – [Russia, China, Koreas, Japan, East Asia]: – 2 ♀♀ [no data, no head].

Hybomitra californica (Marten, 1822) – Canada: 1 ♀ (1) "26-VIII-1953 "B.C. [British Columbia], Squamish | Diamond Head Trail | 400 ft." (2) "W.R. Mason".

Hybomitra captonis (Marten, 1882) – Canada: 1 ♀ (1) "26-VI-21960 B.C. [British Columbia], Mt. Tornhill | nr. Terrace" (2) "B. Heming".

Hybomitra coafinis – [unrecognizable name]: 1 ♀ [no data, no head].

Hybomitra criddlei (Brooks, 1946) – Canada: 1 ♀ (1) "2-VI-1951 Ont. [Ontario], Moynooth | J. F. McAlpine".

Hybomitra distinguenda (Verrall, 1909) – [Europe, Asia]: 1 ♀ [no data, no head].

Hybomitra epistates (Osten-Sacken, 1878) – Canada: 1 ♀ (1) "3-VI-1970 Ont. [Ontario], Smith's Bay | nr. Picton | J.F. McAlpine"; 1 ♀ (1) "24-VI-1954 Ont. [Ontario] | Marmora".

Hybomitra frontalis (Walker, 1848) – Canada: 1 ♀ (1) "7-VI-1954 Q. [Quebec], Fort Chimo | J. G. Mc Alpine"; 1 ♀ (1) "11/15-IX-1967 N. S. [New Scotia], Sable Is. | J. W. Mason".

Hybomitra fulvilateralis (Macquart, 1838) – Canada: 1 ♀ (1) "14-VIII-1953 B.C. [British Columbia], Manning Park | Blackwall, 6000 | J.E.H. Martin"; 1 ♀ (1) "20-VI-1973 B.C. [British Columbia], Aspen Grove | H. G. J. Teskey".

Hybomitra hearlei (Philip, 1936) – Canada: 1 ♀ (1) "27-VI-1948 Ont. [Ontario], Knob Lake | 54°47′, 66°47′" (2) "E.G. Munroe"; 1 ♀ (21) "2-VI-1960 Y. T. [Yukon Territory] La Force | 132°20′ (?), 62°41′, 33°00′" (2) "E.W. Rockburne".

Hybomitra illota (Osten Sacken, 1876) – Canada: 1 ♀ (1) "21-VI-1959 Man. [Manitoba], Bald Hell Hills | 13 mil. | N. Gelnboro" (2) "C.D. Miller"; 1 ♀ (1) "21-VI-1969 Que. [Quebec], Duncan lake | nr. Rupert" (2) "J.F. Mc Alpine".

Hybomitra lanifera (Mc Dunnough, 1922) – Canada: 1 ♀ (1) "6-VIII-1952 [British Columbia] Eva Lake | trail 6000´" | G. J. Spencer"; 1 ♀ (1) "18-VI-1932 Alta. [Alberta], Tonquin Valley | Jasper Nat. Park" (2) "J.D. Gregson".

Hybmomitra lasiophthalma (Macquart, 1838) – Canada: 1 ♀ (1) "11-VI-1943 Ont. [Ontario], Marmora" (2) "G.H. Hammond"; 1 ♀ (1) "19-VI-1960 On. [Ontario], One Sided Lake | Larsson's Camp." (2) "M.R. Mackay".

Hybomitra liorhina (Philip, 1936) – Canada: 1 ♀ (1) "3-VIII-1960 Ont. [Ontario], Gerland" (2) "Kelton & Whitney"; 1 ♀ (1) "29-VIII-1960 B.C. [British Columbia], Moosehorn Lake | 132°07′, 58°10′, 4500´" (2) "R. Pilfre".

Hybomitra longiglossa (Philip, 1931) – Canada: 1 ♀ (1) "9-VI-1949 Nfld. [Newfoundland and Labrador], Gander" (2) "H.A. Hennigan".

Hybomitra lundbecki Lyneborg, 1959 – [Europe, Asia]: 1 ♀ [no data, no wings].

Hybomitra lurida (Fallen, 1817) – Canada: 1 ♀ (1) "23-VI-1955 Cartwright Lab. [Newfoundland and Labrador] | E.E. Sterns".

Hybomitra microcephala (Osten Sacken, 1876) as *Therioplectes microcephalus* – Alaska: 1 ♀ [no date] (1) "Alaska, Obalski" (2) "2919".

Hybomitra minuscula (Hine, 1907) – Canada: 1 ♀ (1) "3-VI-1960 Ont. [Ontario], Byron Bog | Midlesex Co." (2) "Taylor & Wood"; 1 ♀ (1) "13-VI-1961 Ont. [Ontario], Orville" (2) "H.J. Teskey".

Hybomitra montana (Meigen, 1820) – [Europe, Asia]: 2 ♀♀ [no data, no head].

Hybomitra nuda (McDunnough, 1921) – [Canada]: 1 ♀ (1) "28-V-1954 Que. [Quebec], Harrington Lake | Gatinnaeua Pk. [Park]"; 1 ♀ (1) "10-VI-1960 Y.T. [Yukon Territory], La Force | 132°20′ [?], 62°41′, 3300´" (2) "E.W. Rockburne".

Hybomitra opaca (Coquillett, 1904) as *Hybomitra osburni* (Hine, 1904) – Canada: 1 ♀ (1) "29-VI-1931 (1) "B.C. [British Columbia] | Mt. Apex Summerland" (2) A.N. Gartrell"; 1 ♀ (1) "31-VI-1973 Alta. [Alberta] | Waterton Pk. [Park]" | "H.J. Teskey".

Hybomitra osburni Hine = *Hybomitra opaca* (Coquillett, 1904).

Hybomitra pediontis (Mc Alpine, 1961) – Canada: 1 ♀ (1) "27-VI-1955 Sask. [Saskatchewan] | Willow Bunch" | PARATYPE | *Tabanus (Hybomitra) pediontis* (McA) (2) "nº 7353" (3) "A.R. Brooks".

Hybomitra sequax (Willis.) = *Tabanus sequax* Wiliiston, 1887.

Hybomitra sexfaciata (Hine, 1923) – Canada: 1 ♀ (1) "1-VI-1970 Y.T. [Yukon Territory], La Force | 132° 20′, 62° 41′ 1'[?] | 3300´" (2) "E.W.

Rockburne”; 1 ♀ (1) “12-VI-1951 Y.T. [Yukon Territory] | Rampart Houses” (2) “C.C. Loan”.

Hybomitra tarandina (Linnaeus, 1761) as *Tabanus tarandinus* – [North Europe, North Asia, Japan]: 1 ♀ (1) “30-V-1911 Mismug” (2) “Museum Paris | Coll. J. Surcouf 1919” (3) “2860”.

Hybomitra trepida (McDunnough, 1921) – Canada: 1 ♀ (1) “13-VI-1973 B.C. [British Columbia] | McQueen | L. 10 min N | Kamloops”; 1 ♀ (1) “13-VI-195[?] Ont. [Ontario], Blackburn”.

Hybomitra trispila (Wiedemann, 1828) – Canada: 1 ♀ (1) “10-VI-1956 Que. [Quebec], Rupert R.” (2) “J.R. Lonsway”; 1 ♀ (1) “22-VI-1942 Ont. [Ontario] | Marmora” (2) “G.H. Hammond”; 1 ♀ (1) “13-VI-1952 Ont. [Ontario], Marmora” (2) “J.R. McGills”.

Hybomitra tropica (Linnaeus, 1758) as *Tabanus tropicus* – France: 1 ♀ (1) “29-VI-1919 Marly [Marly-le Roi]” (2) “Museum Paris | Coll. J. Surcouf 1919” (3) “2993”; 1 ♀ (1) “24-VI-1912 Ardennes | Vendresse” (2) “Museum Paris | Vendresse [Ardennes] | R. Benoist 19[?] (3) “2994”.

Hybomitra zonalis (Kirby, 1837) as *Therioplectes zonalis* – France: 1 ♀ (1) “1904 Museum Paris | Anticosti | Dr. Schmitt, 1904” (2) “2906”.

Genus *Ochrops* Szilády, 1915 = Genus *Atylotus* Osten -Sacken, 1876

Ochrops fulvus = *Atylotus fulvus* (Meigen, 1820).

Genus *Poeciloderas* Lutz, 1921

Peociloderas quadripunctatus (Fabricius, 1805) – Brazil: 2 ♀♀ (1) “VI-1970 Amazonas | Manaus” (2) “Roppa & Oliveira”; 1 ♀ (1) “26-II-1948 Henriques det. 1991”; 1 ♀ (1) “29-XII-1948 Hanse”; 1 ♀ (1) “IV-1972 “Pernambuco | Caruaru | 900 m” (2) “M. Alvarenga”; 2 ♀♀ (1) “III-1974 Mato Grosso | Dourados” (2) “Alvarenga & Roppa”; 1 ♀ (1) “23-V-1944 Goiás, Anápolis | Ramos; 1 ♀ (1) “I-1934 Goiás | Campinas | Bormeir” (2) “EMBRAPA”; 1 ♀ (1) “30-IV/15-V-1957 Goiás | Brasília | 1000 m” (2) ”Barros & Albuquerque”; 2 ♀♀ (1) “II-1969”, 2 ♀♀ (1) “XI-1971”, 13 ♀♀ (1) “XI-1972” all with “Goiás, Jataí | F.M. Oliveira” also on label (1) 3 ♀♀ (1) “XI-1972 Minas Gerais, Pedra Azul | Seabra Oliveira”, 1 ♀ (1) “XI-1970” and 3 ♀♀ (1) “XII-1972” all with “Minas Gerais | Pedra Azul | Oliveira” also written on label (1); 1 ♀ (1) “IV-1928 Minas Gerais | Poços de Caldas | L.T. Col.” (2) “Osw. 1559”; 1 ♀ (1) “IV-1969”, 11 ♀♀ (1) “II-1969”, 3 ♀♀ (1) “II-1970” all with “Minas Gerais | Serra do Caraça | F.M. Oliveira” written on label (1); 1 ♀ (1) “II-1972 Minas Gerais | Varginha | M.F. Alvarenga”; 1 ♀ [no date] (1) “Rio de Janeiro | Além Paraíba | Faz. Santa Carolina” (2) “J. M. Costa | em suíno”; 1 ♀ (1) “I-1932 Rio de Janeiro | Angra dos Reis | L.T. Col.” (2) “Osw. 1520”; 2 ♀♀ (1) “8-VI-1936 Rio de Janeiro | Angra dos Reis | Travassos & Almeida” (2) “EMBRAPA”; 2 ♀♀ (1) “I-1935 Rio de Janeiro | Angra dos Reis | Japuíba”(2) “EMBRAPA”; 2 ♀♀ (1) “IX-1935 Rio de Janeiro | Angra dos Reis | Jussaral” (2) “D. Mendes Col” (3) “EMBRAPA”; 1 ♀ [no head] (1) “VI-1931 Rio de Janeiro | Angra dos Reis | L.T. Col.”; 1 ♀ (1) “27-X-1963 Rio de Janeiro | Itacuruçá | I.C.M. Carvalho Col”; 1 ♀ (1) “1-XII-1957 Rio de Janeiro | Itaguaí | I. Fernandes Col”; 1 ♀ (1) “7-X-1929 Rio de Janeiro | Itatiaia | Est. Biológica”(2) “EMBRAPA”; 1 ♀ (1) “5-X-1948 Rio de Janeiro | Itatiaia | Faz. Penedo | S.J. Oliveira”; 6 ♀♀ (1) “26-IX-1954 Rio de Janeiro | Itatiaia | Lagoa Azul” (2) “Trav. Barth. Albuquerque & Barros Col”; 2 ♀ (1) “25-X-1930 Rio de Janeiro | Itatiaia | 700 m | J.F. Zikán” (2) “EMBRAPA”; 1 ♀ (1) “13-II-1934”, 1 ♀ (1) “III-1934 Rio de Janeiro | Itatiaia | 700 m” (2) “J.F. Zikán”; 1 ♀ (1) “8-X-1942 Rio de Janeiro | Itatiaia | 700 m” (2) “W. Zikán (3) “1617” (4) “EMBRAPA”; 2 ♀♀ (1) “X-1935 Rio de Janeiro | Jacarepaguá | R. Gagarin” (2) “EMBRAPA”; 1 ♀ (1) “1-II-1956”, 6 ♀ (1) “1-II/8-III-1957 Rio de Janeiro | Petrópolis | Le Vallon, Alt. Mosella” (2) “Albuquerque”; 3 ♀ (1) “XI-1956 Rio de Janeiro | Petrópolis | Le Vallon, Alt. Mosella | 1100 m” (2) “Albuquerque”; 1 ♀ (1) “9-VI-1941 Rio de Janeiro | Rio de Janeiro | Cascadura | Oliveira”; 2 ♀♀ (1) “1-VI-1932”, (1) “IX-1932 Rio de Janeiro | Rio de Janeiro | Corcovado” (2) “L.T. Col.”; 1 ♀ (1) “20-V-1941 Rio de Janeiro | Rio de Janeiro | Deodoro” (2) “W.Zikán” (3) “EMBRAPA”; 1 ♀ (1) “X-1901 Rio de Janeiro | Rio de Janeiro | Parque do Museu Nacional” (2) “Nº PROC 19/994”; 1 ♀ (1) “XI-1966”, 3 ♀♀ (1) “I-1967”, 1 ♀ (1) “XI-1967”, 1 ♀ (1) “II-1969”, 17 ♀♀ (1) “XII-1969”, 1 ♀ (1) “III-1970”, 1 ♀ (1) “I-1972 Rio de Janeiro | Rio de Janeiro | Jacarepaguá | Represa do Rio Grande” (2) “Malaise trap | M. Alvarenga”; 2 ♀ (1) “VII-1969 Rio de Janeiro | Rio de Janeiron | Jacarepaguá | Represa do Rio Grande | Alvarenga”; 1 ♀ (1) “V-1970 Rio de Janeiro | Rio de Janeiro | Jacarepaguá | Represa do Rio Grande” (2) “F.M. Oliveira”; 1 ♀ (1) “VIII-1959 Rio de Janeiro | Rio de Janeiro | Sumaré” (2) “Paulo Borhein”; 2 ♀♀ (1) “21-X-2013”, 4 ♀♀ (1) “4/5-XII-2013”, 2 ♀♀ (1) “20/21-XII-2013 Rio de Janeiro | Mangaratiba | Ilha da Marambaia | Guimarães Col | Guimarães Det. 2014”; 1 ♀ (1) “III-1952 Rio de Janeiro | Teresópolis | Travassos Col”; 1 ♀ (1) “IX-1929 Terezópolis | Off. Victor de Miranda Ribeiro” (2) “Nº PROC 11/581” (3) “MUSEU NACIONAL”; 1 ♀ (1) “5- XI-1954 Rio de Janeiro | Vassouras | Palmital” (2) “S.J. Oliveira”; 1 ♀ (1) “X-1925 Rio de Janeiro | Dario Mendes Col” (2) “EMBRAPA | 4127”; 1 ♀ (1) “27-X-1963 São Paulo | Bocaina | P. Iide”; 4 ♀♀ (1) “5-XI-1970 São Paulo | Bocaina | Fruticultura | Albuquerque Col”; 1 ♀ (1) “XI-1993 São Paulo | Cotia” [no head] | B.R.L. Col”; 1 ♀ (1) “XI-1993 São Paulo | Cotia” (2) “933” (3) “B.R.L. Col”; 1 ♀ (1) “X-1933 São Paulo | São José dos Campos | H.S. Lopes”; 1 ♀ (1) “2-II-1917 São Paulo | Bosque de Santos” (2) “MUSEU NACIONAL”; 1 ♀ (1) “9-IV-1936 São Paulo | São Paulo | Jardim Cidade | Morretes” (2) “EMBRAPA”; 1 ♀ (1) “IV-1939 São Paulo | Est. Faz Casa Grande | Z. Vaz Col” (2) “E.S.A. Parasit. Nº 16193”; 1 ♀ (1) “21-X-1934 São Paulo | Parque do Estado | L. Trav. F° Col” (2) “EMBRAPA”; 1 ♀ (1) “I-1933 São Paulo | J. Lane” (2) “EMBRAPA”; 8 ♀♀ (1) “III-1971 Santa Catarina | Curitibanos | Paulo Iide”; 1 ♀ (1) “II-1972 Santa Catarina | Curitibanos | F.M. Oliveira”; 4 ♀ (1) “I-1960”, 4 ♀♀ (1) “XII-1960”, 10 ♀♀ (1) “II-1961”, 4 ♀♀ (1) “II-1962” all specimens with labels (2) “Santa Catarina | Nova Teutônia | 27° 11′ S, 52° 23′ L, 300-500 m | Fritz Plaumann”; 1 ♀ (1) “XI-1934 Rio Grande do Sul | Jaguaretê | Parko”; 1 ♀ [no date] (1) “Museu Nacional | Pr. Itatiaia | Col E. May” (2) “Nº PROC 11/528”; 1 ♀ [no date] (1) “Nº 11/584”. Unidentifid specimens of Genus *Poeciloderas*: 4.

Genus *Tabanus* Linnaeus, 1758

Tabanus africanus Gray, 1832 – Republic of Mozambique: 1 ♀ (1) “1907 Museum Paris | Mozambique | Provincia de Gorongoza | Tedos de L’Urema | G. Vssé, 1907” (2) “2973”.

Tabanus albitibialis Macq. = *Tabanus silvanus* Ricardo, 1908.

Tabanus albocirculus Hine, 1907 – Panama: 1 ♀ (1) 1-IX-1940 Panama | Panama Prov. | Moja Poll” (2) “242” | (3) “R.P.”

Tabanus alexandrinus = *Dasyrhamphis nigritus* (Fabricius, 1794).

Tabanus amaenus Walker, 1848 as *Tabanus griseus* – France: 2 ♀♀ (1) “7-VI-1917 Villiy le seo | N.N.N.” (2) “Museum Paris | Coll. R.

Benoist, 1924" (3) "2894" and (3) "2895" each one; 1 ♀ (1) "1-VI-1920 Les Guerreaux" (2) "2833".

Tabanus antarticus, Linnaeus 1758 as *Tabanus antarticus* Kroeber [in error] – Brazil: 1 ♀ (1) "26-VI-1959 Ter. Amapá | Rio Amapari | Anicohi" (2) "J. Lane Col"; 1 ♀ (1) "VI-1972 Amazonas | Manaus | Roppa & Oliveira Col"; 1 ♀ (1) "1944 Pará | Belém" (2) "Damasceno"; 4 ♀♀ (1) "1/16-XII-1966 Pará, Belém, Utinga" (2) "S.J. Oliveira Col"; 2 ♀♀ (1) "XI-1972 Goiás, Jataí".

Tabanus antarticus affinis – Brazil: 1 ♀ (1) "9-IV-1954 Amazonas, Manaus | Elias & Roppa Col" (2) "DZ 9/59"; 1 ♀ (1) "XI-1954 Amazonas | Manaus" | Elias & Roppa Col" (2) "DZ 9/959".

Tabanus ardens Wiedemann, 1821 – India: 1 ♀ (1) "1911 Inde Meridionale | Trichinopoly | P. Caius" (2) "2798".

Tabanus ater = *Tabanus atratus* Fabricius 1775.

Tabanus aterrimus = *Hybomitra aterrima* (Meigen, 1820).

Tabanus atratus Fabricius 1775 as *Tabanus ater* – Canada: 1 ♀ (1) "12-VI-1947 Que. [Quebec], Marmora" (2) "H. Kellog".

Tabanus atripes Van der Wulp, 1885 as *Tabanus atripes* Wied. [in error] = *Ancala fasciata* Fabricius, 1775.

Tabanus auribundus Schuurmans-Stekhoven, 1926 – Morocco: 2 ♀♀ (1) "20-IV-1918 Casablanca" (2) "2982" and (2) "2983", each one.

Tabanus autumnalis Linnaeus, 1761 – France: 1 ♀ (1) "IV-1914 Museum Paris | Manoncourt-em-Woëvre | Meurthe & Moselle | R. Benoist" (2) "2976"; 1 ♀ (1) "6-VI-1917 (1) "Rambouillete" (2) "2977".

Tabanus barbarus Coquebert, 1804 as *Atylotus barbarus* Coquillet – Morocco: 1 ♀ (1) "II-1886 Museum Paris | Tangier".

Tabanus besti Surcouf, 1907 – Ivory Coast: 2 ♀♀ both specimens with label (1) "Museum Paris | Haute Cote D'Ivoire | Danaé, Forte Hittos | A. Chevalier 1910" (2) "2779" and (2) "2780", each one.

Tabanus bifarius Lowe, 1858 as *Atylotus bifarius* Loew – France: 1 ♀ (1) "VIII-1960 Alpes Maritmes | Théoule" (2) "2844".

Tabanus bigoti Bellardi, 1859 – Guatemala: 1 ♀ (1) "1903 San Cristobal Trawitx | Bequart Det" (2) "EMBRAPA". Colombia: 1 ♀ (1) "X-1934 Putomato | *Gymonochela bigoti* Belli | Apolimar Maria".

Tabanus biguttatus Wiedemann, 1830 – Ethiopia: 1 ♀ [no date] (1) "Museum Paris | Abyssinie | entre Haratassisabeba | coll Abonhoure 1909" (2) "2766". Republic of Mozambique: 1 ♀ (1) "XI-1928/I-1929 Museum Paris | Mozambique | Nov Chupanga | J. Surcouf" (2) "2761".

Tabanus blanchardi = *Tabanus secedens* Walker, 1854.

Tabanus bovinus Linnaeus, 1758 – [Europe, North Africa and Asia]: 2 ♀♀ [no date] both with label (1) "Instituto de Biologia | Entomologia Agricola | Rio de Janeiro" (2) "nº 4.168" and (2) "14.169 and (3) "EMBRAPA", each one specimen; 1 ♀ (1) "13-IX-1923 Vindrene" (2) "2978"; 1 ♀ [no date] (1) "Vogesen | Fischbödel | G. Bouvier det *Tabanus bovinus*" (2) "EMBRAPA"; 1 ♀ (1) "VI-1922 Les Guerreaux | Museum Paris | J. Surcouf 1919" (2) "2979".

Tabanus bromius Linnaeus, 1761 – France: 2 ♀♀ (1) "VI-1914 Andennes | Vendresse" (2) "Museum Paris | Vendresse | Ardennes | R. Benoist 19[??]" (3) "2951" and (3) "2952", each one. Germany: 1 ♀ (1) "VI/VII-1937 Riesengeb | Brckenberg, 850 m | M.P. Riedel leg"; 1 ♂ (1) "26-VI-1918 Elise" (2) "2863"; 1 ♂ (1) "19-VI-1918 Yerrers" [no right wing].

Tabanus canus Karsch, 1879 – Gabon: 1 ♀ (1) 1901 "Museum Paris | Bas-Ogoué | entre Lambaréne et le mer | E. Haug" (2) "2775".

Tabanus chrysurus Loew, 1858 – Japan: 1 ♀ (1) "Museum Paris | Nippon, Moyen | Kofou | J. Drouart de Lezey 1906" (2) "2923"; 1 ♀ [no date] (1) "Museum Paris | Nippon, Moyen | env. De Tokio et Alpes de Nikko | J. Harmand 1901" (2) "2924".

Tabanus cinnamoneus Doleschall, 1858 – Tasmania: 1 ♀ (1) "IV-1946 (1) "Museum Paris | Tasmanie | Verreaux".

Tabanus claripennis (Bigot, 1892) – Brazil: 3 ♀♀ (1) "V-1969 Ceará | Barbalha | M. Alvarenga Col"; 4 ♀♀ (1) "IV-/V-1940 Ceará | Timbauvas | Mangabeira; 1 ♀ (1) "19-IX-1926 Pernambuco | Tapera" (2) "96094" (3) "EMBRAPA"; as *Tabanus comitans* – 1 ♀ X-1912 Mato Grosso | Juína | Serra do Norte | Roquette" (2) "Nº11/591"; 5 ♀ (1) "26-VIII-1940", 1 ♀ (1) "I-1955 Mato Grosso | Salobra" (2) "Com. IOC"; 2 ♀♀ (1) "XI-1972 Minas Gerais | Pedra Azul | Seabra & Oliveira Col"; 4 ♀♀ (1) "X-1979 Minas Gerais | Santa Vitória | F.M. Oliveira"; 1 ♀ (1) "14-IV-1950 Rio de Janeiro [Seropédica] | km 47 | Sondal"; 1 ♀ (1) "12-III-1944 Rio de Janeiro | Rio de Janeiro | Deodoro | W. Zikán Col" (2) "EMBRAPA"; 1 ♀ (1) "V-1931 Rio de Janeiro | Rio de Janeiro | Manguinhos | L.T. Col" (2) "10.005"; 1 ♀ (1) "I-1963 Rio de Janeiro | Nova Iguaçu | P. Iide"; 1 ♀ (1) 18-III-1909 Rio de Janeiro | Rio de Janeiro | Manguinhos" (2) "Museu Nacional Nº PROC 11/590". Paraguay: 1 ♀ (1) "V-1944 Paraguay | Isla Valle | Mis. Cient. Brazil Col". Argentina: 1 ♂ (1) "1919 Argentina | Rio Salgado" (2) "Museum Paris | E. Le Moult". ATLFO.

Tabanus conformis Walker, 1848 as *Tabanus socialis* – Ivory Coast: 1 ♀ (1) "4-X-1905 Museum Paris | Grand Bassoum en ville | E. Brumpt 1906" (2) "20608" (3) "nº 11/594" (4) "2810".

Tabanus congolensis Ricardo, 1908 – Republic of Congo: 1 ♀ (1) 1925 Museum Paris | Congo Française | Karamaiuen | Cn. Fourneau" (2) "2995".

Tabanus cordiger Meigen, 1820 – France: 1 ♀ (1) "12-VI-1990 Camargue" (2) "2971"; 1 ♀ (1) "26-VI-1912 Ardennes | Vendrresse" (2) "2972".

Tabanus cordigeroides Surcouf, 1922 – Algeria: 2 ♀♀ (1) "21-IX-1921 Djama" (2) "2965" and (2) "2966", each specimen.

Tabanus corpulentus Brèthes, 1910 – Brazil: 1 ♀ (1) "XI-1973 Rondônia | Vilhena | Alvarenga & Roppa Col"; 3 ♀♀ (1) "VI-1930", "1-VI-1931", "1932 Minas Gerais | Paraopeba" (2) "Vital Souza" and (2) "Nº PROC 16.628", (2) "Nº PROC 16.629", (2) "Nº PROC 16.301", each one; 1 ♀ (1) "X-1969 Espírito Santo | Colatina | F.M. Oliveira"; 1 ♀ (1) "XI-1923 Chapada [?]"; 1 ♀ (1) "XI-1923 (1) "Bandeira[?]". ATLFO.

Tabanus discifer Walker, 1850 – Brazil: 1 ♀ (1) "II-VI-1961 Amapá | Porto Santana | ICOMI | J.C.M. Carvalho Col"; 1 ♀ (1) "3-VI-1955 Amazonas | Manaus | Elias & Roppa Col"; 1 ♀ (1) "1950 Amazonas | Tabatinga | J.C.M. Carvalho Col | Alan Stone det"; 1 ♀ (1) "1/16-XII-1966 Pará | Belém | Utinga | S.J. Oliveira Col".

Tabanus discus Wiedemann, 1829 – Brazil: 4 ♀♀ (1) "4/5-XII-2013 Rio de Janeiro | Mangaratiba | Ilha da Marambaia | Guimarães Col and Det".

Tabanus distinguenda (Verrall, 1909) – France: 1 ♀ (1) "1919 Museum Paris | Coll. J. Surcouf" (2) "2915"; 1 ♀ (1) "7-VI-1922 Foret de Carnelle | S. & O., F. Lecerf" (2) Museum Paris | Coll. Surcouf 1919" (3) "2916".

Tabanus ditaeniatus = *Atylotus ditaeniatus* (Walker, 1854).

Tabanus exclusus Pandelle, 1883 – France: 2 ♂♂ (1) “1917 Museum Paris | Mont Verdun | Rhône, 600 m | C. Pierre 1917” (2) “2974” and (2) “275” each one.

Tabanus farinosus (Szilády, 1915) as *Tabanus pulchrusourirensis* – Argelia: 2 ♀♀ [no date] both with labels (1) “Algérie | Oujama | J. Surcouf 1906” (2) “2911” and (2) “2917”, each one.

Tabanus fasciatus DeGeer, 1776 – Republic of Congo: 2 ♀♀ (1) “1906 Museum Paris | Ouesso | N’Goko Sanga | Dr. J. Gravot 1906” (2) “2823” and (2) “2834”, each one.

Tabanus fortis Fairchild, 1961 – Brazil: 1 ♀ (1) “X-1957 Ter. Amapá, Serra do Navio | Bicelli”.

Tabanus fraternus Macquart, 1846 – Mozambique: 1 ♀ (1) “II-1929 Museum Paris | Zambéze | Chiramba | P. Lesne 1929” (2) “FEVE” (3) “2777”.

Tabanus fulvicornis Kröber, 1931 – [Peru, Ecuador]: 1 ♀ [no date] (1) “Danemark, Dr. Nielsen” (2) “2814” [probably misindentified].

Tabanus fulvimedius Walker, 1848 – Taiwan [or Republic of China]: 1 ♀ (1) “1919 Formosa” (2) “Museum Paris | Coll. Surcouf (3) “2996”.

Tabanus fulvus = *Atylotus fulvus* (Meigen, 1820).

Tabanus fuscus Wiedemann, 1819 – Brazil: 3 ♀♀ (1) “XI-1972 Minas Gerais, Pedra Azul | Seabra & Alvarenga”; 2 ♀♀ (1) “X-1971”, “X-1972 Espírito Santo, Linhares | F.M. Oliveira”; 2 ♀♀ (1) “X-1972 Espírito Santo | Linhares | Alvarenga & Roppa”; 1 ♀♀ (1) “IX-1972 Espírito Santo | Linhares | P. C. Elias”; 28 ♀♀ (1) “IX-1972 Espírito Santo | Linhares | Alvarenga & Roppa”; 1 ♀ (1) “XII-1931 Rio de Janeiro | Angra dos Reis” (2) “E.S.A.M.V. Parasitol. Nº 15493”; 2 ♀♀ (1) “XII-1931 Rio de Janeiro | Angra dos Reis | Japuhiba” (2) “EMBRAPA”; 1 ♀ (1) “I-1934 [Rio de Janeiro] Angra dos Reis | Jussaral | L. Travassos | *impressus* Wied.” (2) “EMBRAPA”; 1 ♀ (1) “XII-1934 [Rio de Janeiro] Angra dos Reis | Jussaral”; 1 ♀ 91) “I-1935 [Rio de Janeiro] Angra dos Reis | Japuhiba” | *Chelotabanus impressus* (2) “EMBRAPA”; 5 ♀♀ (1) “24-X-1936, “5-XI-1944”, “28-IV-1944”, “XII-1945”, “I-1967 Rio de Janeiro | Distrito Federal [Rio de Janeiro] | Deodoro | W. ZIkán” (2) “EMBRAPA”; 1 ♀ (1) “3-II-1942 [Rio de Janeiro], Rio [de Janeiro] | Campo Grande | *impressus*” (2) “EMBRAPA”; 1 ♀ (1) “I-1967 Rio de Janeiro | Rio de Janeiro | Represa do Rio Grande | Malaise trap | M. Alvarenga”; 1 ♀ /91) “XII-1969 Rio de Janeiro | Rio de Janeiro | Represa do Rio Grande | M. Alvarenga”; 1 ♀ (1) “3-III-1934 [Rio de Janeiro Represa] “Carmorim” | C. Berla”; 1 ♀ (1) “18-VI-1934 Rio de Janeiro | [Seropédica] Est. Rio-São Paulo, km 47”; 1 ♀ (1) “2-II-1944 [Rio de Janeiro, Seropédica] Est. Rio-São Paulo, km 47” | H. Montenegro | *impressus* Wied.” (2) “EMBRAPA”; 1 ♀ (1) “2-X-1947 Rio de Janeiro [Seropédica] | Est. Rio-São Paulo, km 47 | Wygod | *impressus* Wied.” (2) “EMBRAPA”; 1 ♀ (1) “X-1947 Rio de Janeiro [Seropédica] | Est. Rio-São Paulo, km 47 | Wygod Col” (2) “EMBRAPA” (3) “*Tabanus impressus*”; 1 ♀ (1) “1-XI-1957 Rio de Janeiro [Seropédica] | Est. Rio-São Paulo, km 47 | Zikán (2) “EMBRAPA”; 1 ♀ (1) “28-X-1958 Rio de Janeiro | Itaguaí [Seropédica, Est. Rio-São Paulo], km 47 | M. Rodrigues”; 1 ♀ (1) “10-IX-1960 Rio de Janeiro [Seropédica] | UR [Universidade Rural], km 47 | Rodolfo Torres”; 1 ♀ (1) “1-X-1968 Rio de Janeiro, Itaguaí [Seropédica], Universidade Rural | Perachi”; 1 ♀ (1) “1-XII-1997 [Rio de Janeiro] Itaguaí [Seropédica] | L. Fernandes Col”; 1 ♀ (1) “29-VI-1934 Rio de Janeiro | Itatiaia, 816 m | Est. Biológica | J.F. Zikán” (2) “EMBRAPA”; 1 ♀ (1) “7-XII-1951 Rio de Janeiro | Itatiaia, 700 m | J.F. Zikán” (2) “EMBRAPA”; 1 ♀ [no date] (1) “Rio de Janeiro | Itatiaia” | J.F. Zikán” (2) “EMBRAPA”; 1 ♀ (1) “I-1934 Rio de Janeiro | Petrópolis” (2) “EMBRAPA”; 1 ♀ [no date] (1) “[Rio de Janeiro] Itatiaia | Mont Serrat | Col Bruno Lobo” (2) “N º PROC 11/687”; 1 ♀ (1) “10-VI-1902 [Rio de Janeiro, Duque de Caxias] Mauá | Cardoso Moreira” (2) “Nº PROC 11/998”; 1 ♀ (1) “12-XII-1948 São Paulo | Pirassununga | Machado Alceu”; 1 ♀ (1) “1936 São Paulo | São José dos Campos | H.S. Lopes” (2) “EMBRAPA”; 1 ♀ (1) “2/3-VI-1949 Hanse”; 3 ♀♀ (1) “19-XI-1948”, “21-III-1948” [no other data]; 1 ♀ [no date] (1) “Nº PROC 11/630”; 1 ♀ (1) “18-VI-1946 “*Chetotabanus fuscusi*”; 1 ♀ (1) “24-VI-1949 Fensi”; 1 ♀ (1) “8-VI-1941” [no other data] ; 1 ♀ [no date (1) “Tabanida | *Tabanus impressus*” (2) “EMBRAPA”; 1 ♀ [no date] (1) “*Tabanus impressus*” (2) “Nº PROC 11/638”.

Tabanus gabonensis = *Tabanus secedens* Walker, 1854.

Tabanus glaucopis Meigen, 1820 – France: 1 ♀ (1) “13-VI-1923 Museum Paris | Vendresse [Ardennes] | R. Benoist” (2) “2692”; 1 ♀ (1) “13-VI-1924 Museum Paris | Vendresse [Ardennes], R. Benoist” (2) “2691”.

Tabanus gratus Loew, 1858 – Sudan: 2 ♀♀ [no date] both with labels (1) “Soudan | D’Laveran” (2) “2940” and “2941”, each specimen; 1 ♀ [garbled label].

Tabanus griseus = *Tabanus amaenus* Walker, 1848.

Tabanus guyannensis Macquart, 1846 – French Guiana: 1 ♀ (1) “1914 Guyane Française | Kouru | R. Benoist” (2) “Museum Paris | Juillet | 2792”. Brazil: 2 ♀♀ (1) “15-VIII-1949 Amapá | Oiapoque”; 1 ♀ (1) “II-VI-1961 Amapá | Porto Santana | ICOMI | J.C.M. Carvalho Col”; 2 ♀♀ (1) “VIII-1958 Elias e Roppa Col”.

Tabanus hookeri Knab, 1915 – Brazil: 1 ♀ (1) “1-XI-1937 São Paulo | Engenheiro Lefevre [Santo Antônio do Pinhal] | Trav. Lopes & Oiticia Col”. Paraguay: 1 ♀ (1) “II-1944 Paraguay | Assunción | Mis. Cient. Brazil Col”. Argentina: 1 ♀ (1) “23-XI-1957 Argentina | Buenos Aires | Boulogne Sur Mer | H.S. Lopes”.

Tabanus humilis Coquillett, 1898 – Japan: 2 ♀♀ (1) “13-VIII-1907 Kumanotaira | pr. Karuizawa” (2) “Museum Paris | Nippon, Moyen | E. G allois 1912” (3) “2985” and (3) “2986”, each one specimen.

Tabanus importunus Wiedemann, 1828 – French Guiana: 1 ♀ (1) “1914 Guyane Française | Gourdonville | R. Benoist” (2) “Museum Paris | Aout | *Tabanus testaceus*” (3) “2791”. Brazil: 1 ♀ (1) “15-VIII-1949 Amapá, Oiapoque | A. Stone det”; 3 ♀♀ (1) “II-VI-1961 Amapá | Porto Santana | ICOMI | J.C.M. Carvalho Col”; 1 ♀ (1) “X-1959 Ter. Amapá | Serra do Navio | Bicelli”; 1 ♀ (1) “II-VI-1961 Amapá | Serra do Navio | ICOMI | J.C.M. Carvalho Col”; 2 ♀♀ (1) “XI-1954”, “21-V-1955 Amazonas | Manaus (2) DZ 9/59 | Elias & Roppa Col”; 1 ♀ (1) “7-IV-1940 Pará | Marajó | Horse trap | C.E.L.V.A.”; 16 ♀♀ [no date] all with label (1) “Pará | Marajó | Faz. Santa Maria”; 1 ♀ (1) “1940 (2) “Pará | Belém | Aurá | horse trap | C.E.L.V.A.” ; 3 ♀♀ (1) “1/16-XII-1966 Pará | Belém | Utinga | S.J. Oliveira Col”; 1 ♀ (1) “VIII-1957 Bahia | Bolandeira | D. Albuquerque”; 1 ♀ (1) “IX-1947 Minas Gerais | B. R. Claro | C Carvalho Col”; 1 ♀ (1) “27-IV-2013”, 2 ♀♀ (1) “10-X-2013”, 3 ♀♀ (1) “4/5-XII-2013 Rio de Janeiro | Mangaratiba | Ilha da Marambaia | Guimarães Col and det”; 1 ♀ (1) “11-V-1961 Rio de Janeiro | São João de Meriti | J. Cruz Col”; 1 ♀ (1) “31-VI-1937 Rio de Janeiro | Rio de Janeiro | Deodoro | W. Zikán Col” (2) “696” (3) “EMBRAPA”; 1 ♀ (1) “5-I-1953 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | D. Mendes”; 1 ♀ (1) “18-IV-1948 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | W. Zikán Col” (2) “EMBRAPA”; 3 ♀♀ (1) “1942,

(1) “10-IV-1944”, (21) “ 10-IV-1949 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | D. Mendes Col” (2) “EMBRAPA”; 1 ♀ (1) “24-II-1944 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | H. Mont. Netto Col” (2) “EMBRAPA”; 1 ♀ (1) 8-IX-1949 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | Arthur Leg” (2) “EMBRAPA”; 1 ♀ (1) “21-i?-1943 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | [Ilegible] Leg”; 1 ♀ (1) “19-III-1943 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | Wygod leg”; 2 ♀♀ (1) “15-IV-1953”, (1) “2-III-1959” Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | W. Zikán Col” (2) “EMBRAPA”; 1 ♀ (1) “9-I-1970 Rio de Janeiro | Seropédica | Est. Rio São Paulo, Km 47 | Alojamento UFRRJ | Laerte”; 1 ♀ [no date] (1) “Rio de Janeiro | Teresópolis” (2) “MUSEU NACIONAL | Off. Victor de M. Ribeiro (3) “Nº PROC 11/630”; 4 ♀♀ (1) “1-VI-1949 [Santa Catarina [?] São Joaquim | Icarae”; 1 ♀ (1) “15-IX-1966 | URB | P.P. Abilio”; 2 ♀♀ [no data]. ATLFO.

Tabanus intermedius Tendeiro, 1964 – [Bissau Guinea]: 2 ♀♀ (1) “1919 [no procedence] (1) “Museum Paris, Coll. Surcouf” (2) “2945” and (2) “2946”, each one.

Tabanus latipes (Macquart, 1838) – [Senegal to Sudan]: 1 ♀ (1) “1924 Museum Paris | Mission Lenfan | 1924” (2) “2813”.

Tabanus laverani Surcouf, 1907 – [Republic of Congo]: 2 ♀♀ [no date] (1) “Mte. Samaha | D’Laubouene (2) “2793” and (2) “2794”. Mozambique: 1 ♀ (1) “1906 Museum Paris | Moçambique | Vallé du Pongoué | Guengére | G. Vsse, 1906” (2) “2918”.

Tabanus leleani Austen, 1920 – Algeria: 2 ♀♀ [no date] (1) “Algérie | Ojama | J. Surcouf” (2) “2969” and (2) “2970”.

Tabanus lineola Fabricius, 1794 – Canada: 1 ♀ (1) “5-VI-1962 Ont. [Ontario] | Rondeau Park | S.M. Clark”; 1 ♀ (1) “22-VI-1958 Ont. [Ontario] | Marlen | H.J. Teskey”; USA: 1 ♀ (1) “7-VI-1936 N.Y. [New York, Oswego] (2) “200”; 1 ♀ (1) “18-V-1934 Fla. [Florida] Miami | G.B. Fairchild col”; as *Tabanus lineola scutelaria* Wal. - 1 ♀ (1) “VI-1939” “Wyoming | Torrington | G.B. Fairchild Col, Det Fairchild, 1939”. Brazil: 799 ♀♀, 167 ♂♂ specimens from Amapá, Amazonas, Pará, Ceará, Goiás, Minas Gerais, Rio de Janeiro, Santa Catarina and Rio Grande do Sul lacking specific identification.

Tabanus lunatus Fabricius, 1794 as *Atylotus lunatus* – Algeria: 2 ♀♀ [no date] (1) “Algerie | Djelfa | J. Surcouf” (2) “2954” and (2) “2960”.

Tabanus lutzi Kröber, 1934 – Brazil: 7 ♀♀ (1) “VI-1972 Amazonas | Manaus | Roppa & Oliveira Col”.

Tabanus maculatissima = *Euancala maculatissima* (Macquart, 1838).

Tabanus marginalis Fabricius, 1805 – Canada: 1 ♀ (1) “3-VIII-1967 Que. [Quebec], Kazabazua | H.J. Teskey”.

Tabanus micans (Meigen, 1904) – France: 2 ♀♀ (1) “V-1914 Museum Paris | Manoncourt em Woevre | Meurthe & Moselle | R. Benoist” (2) “2961”; 1 ♀ (1) “1919 Friedrich roda” (2) “Museum Paris | Coll. E. Séguy 1919” (3) “2844”; 1 ♀ (1) “VII-1917 “Rambouillet” (2) “Museum Paris | Coll. E. Séguy 1919” (3) “2865”.

Tabanus montana (Meiger, 1820) – [Europe, Asia]: 1 ♂ [no date] (1) “Frankf. Od. | M. P. Riedel | *Tabanus montanus* Mg. Riedel det” (2) “EMBRAPA”; 1 ♀ [no date] (1) “2865”; 1 ♀ 27-VI-1917 (1) “EMBRAPA”; 1 ♀ (1) “VI-1917 Movement em Vern | jun 1917” (2) “2811”; 1 ♀ [no date] (1) “Danemark | Dr. Hielsen” (2) “2815”; 1 ♀ [no date] (1) “Museum Paris | Canada | Isle dAnticosti | T. Oblaski” (2) “2920”.

Tabanus nebulosus DeGeer, 1776 – Brazil: 1 ♀ (1) “XI-1973 Rondonia | Vilhena 580 m | Alvarenga & Roppa Col”; 1 ♀ (1) “1951 Bahia | Salvador”; 1 ♀ (1) “X-1912 Mato Grosso | Vale do Rio Juína | Serra do Norte” (2) “Nº PROC 11/634”; 1 ♀ (1) “XI-1923 “Chapada”. Paraguay: as *Tabanus nebulosus ornativentris* – 1 ♀ (1) “I-1944 Paraguay | Porto Gil | Est. Lá | Mis. Cient. Brazil Col”.

Tabanus nigrovittatus Macquart, 1847 – Canada: 1 ♀ (1) “25-VI-1939 N. B. | Tabunsitac | J. McDunnough”; 1 ♀ (1) “13-VIII-1943 Parrebor N. S. | Ottawa House | J. McDunnough”.

Tabanus obscurihirtus Ricardo, 1908 – Republic of Congo: 1 ♀ [no date] (1) “Museum Paris | Congo | H’Tem | C. Cotes”.

Tabanus obsoletus Wiedemann, 1821 – Brazil: 4 ♀♀ [no date] (1) “Espírito Santo, Vitória | Dr. M. Leitão”; 1 ♀ (1) “19-III-1989 Rio de Janeiro | Magé” (2) “Museu Nacional”; 1 ♂ (1) “19-X-1956 SP-L” [São Paulo – Litoral] (2) “S. Vicente | 2498 | Rabro col”. ATLFO.

Tabanus occidentalis Linnaeus, 1758 – Brazil: 8 ♀♀ (1) “20/21-XII-2013 Rio de Janeiro | Mangaratiba | Ilha da Marambaia | Guimarães Col and Det”; 5 ♀♀ (1) “X-1975 A.L. Henriques det 1993”; 1 ♀ (1) “II-1956 [Rio de Janeiro] Petrópolis | Alto Mosella | D’Albuquerque 1993”; 1 ♀ (1) “10-XI-1939” [no procedence] “A.L. Henriques det.”; as *Tabanuns dorsiger* var. *dorsovittatus* (Wiedemann, 1821) – 1 ♂ (1) “XII-1953 São Paulo | Osasco | J. Lane”; as *Tabanus dorsiger* var. *modestus* Wiedemann, 1821 – 1 ♀ (1) “18-VI-1957 Terr. Amapá | Rio Felício | *plangens*, O. Castro det”; 1 ♀ (1) “1940 Pará | Belém | Aurá” (2) “horse trap | C.EL.V.A. | *N. plangens*, O. Castro det.”; as *Tabanus dorsiger* var. *stenocephalus* Hine, 1906 – 1 ♀ (1) “1940 Pará | Belém | Aurá” (2) “horse trap | C.E.L.V.A.” (3) “T. *dorsiger stenocephalus* Hine | if it is *N. occidentalis* L. from Wied. | det for Castro” (4) “*N. occidentalis* L. | O. Castro det”; 1 ♀ [no date] (1) “São Paulo | Vera Cruz | 203 | A. Ramalho col”.

Tabanus oculus Walker, 1848 – Brazil: 1 ♀ (1) “1944 Pará | Belém | 249 | Damasceno”.

Tabanus olivaceiventris Macquart, 1847 – Brazil: 3 ♀♀ (1) “1/16-XII-1966 Pará | Belém | Utinga | S J. Oliveira Col”; 3 ♀♀ (1) “VII-1930 Amazonas | Manaus | Aurá” | Mangabeira”; 7 ♀♀ [no data].

Tabanus par Walker, 1854 – Mozambique: 1 ♀ (1) “1906 Museum Paris | Moçambique | Vallée du Pongoué | Guengére | G. Vsse 1906 [col]” (2) “1917”.

Tabanus paradoxus Jaennicke, 1866 – [Austria]: 1 ♂ (1) “1921 3007”; 1 ♀ (1) “VII-1910 Ruggburg” (2) “3008”; 1 ♀ [no date] (1) “Museum Paris Callan | Var, L. Berland 1921 | juillet (2) “2947”.

Tabanus piceiventris – Brazil: 1 ♀ (1) “2-VIII-1959 Ter. Amapá | Rio Felício”; 1 ♀ (1) “VIII-1958, 11 ♀♀ (1) “22-IV-1955” Amazonas | Manaus | Elias & Roppa Col” (2) “DZ 9/59”; 4 ♀♀ (1) “2-V-1950 aAmazonas | Rio Itacorai | J.C.M. Oliveira Col” (2) “Henriques det”; 1 ♀ (1) “X-1944 Pará | Belém | 246 | Damasceno”; 1 ♀ (1) “1/16-XII-1966 Pará | Belém | S.J. Oliveira Col”; 1 ♀ (1) “XI-1973 Rondônia | Vilhena | Alvarenga & Roppa Col”; 2 ♀♀ (1) “XI-1969 Minas Gerais | Serra da Caraça | F.M. Oliveira Col”.

Tabanus pulchrus ouririensis = *Tabanus farinosus* (Szilády, 1915).

Tabanus punges = *Haematopota pungens* Doleschall, 1856

Tabanus quadrisignatus Ricardo, 1908 – Republic of Congo: 2 ♀♀ [no date] both with label (1) “Museum Paris | Congo | Libnzolo | D’Allain” (2) “2802” and (2) “2803”, each one.

Tabanus quinquevittatus Wiedemann, 1821 – Canada: 1 ♀ (1) "14-VI-1954 Ont. [Ontario] Marmora | C. Boyle"; 1 ♀ (1) "14-VI-1954 (1) "Ont. (Ontario) Cathan | L.A. Miller".

Tabanus rectus Loew, 1858 – France: 1 ♀ (1) "9-VI-1915 St. Remy a Var | R. du Buysson" (2) "Museum Paris | Coll. R. du Buyusson, 1900" (2) "2964".

Tabanus roubaudi Mackerras & Rageau, 1958 – Mozambique: 1 ♀ (1) "8-X-1915 Amalvagas" (2) "Museum Paris | Moçambique | Nov Chupanga"; 1 ♀ (1) "XII-1928/I-1929 [no procedence] (1) J. Surcouf" (2) "2778".

Tabanus rousselii Macquart, 1839 as *Tabanus roussel* – Argelia: 1 ♂ (1) "VI-1839 Ouled Messelem" (2) "Museum Paris | Algérie | P. Lesne VI-1897 [det]" (3) "2870".

Tabanus rubripes Macquart, 1838 – Brazil: 1 ♀ (1) "7-IV-1940 Marajó (Pará) | 250 | horse trap | C.E.L.V.A."

Tabanus ruficus Palisot de Beauvois, 1807– Republic of Congo: 1 ♀ [no date] (1) "Museum Paris | Congo | Brazzaville | Rouband 07" (2) "2758"; 1 ♀ (1) "1917 "Museum Paris | Congo Belge | Oullé Bouta | Dr. Bubois | L. Burgeon 1917" (2) "2759".

Tabanus rusticus (Linneaus, 1767) – France: 1 ♀ (1) "1-VI-1920 Les Guerreaux" (2) "2796"; 1 ♀ [no date] (1) "Ardennes, Vendresse" (2) "2795". Republic of Congo: 1 ♀ [no date] (1) "Museum Paris | Congo | Linzolo | Dr. Allain" (2) "2802".

Tabanus secedens Walker, 1854 as *Tabanus blanchardi* – Ivory Coast: 1 ♀ (1) "XII/1930/IV-1931 Cote D'Ivoire | Daloa" (2) "Museum Paris | 12-1930/4-1931 |Ch. Alluad & P.A. Cahppuis" (3) 2816"; as *Tabanus gabonensis* – Republic of Congo: 1 ♀ (1) "X-1908 Museum Paris | Congo Française | Ouesso [Sangha] | Dr. J. Kárandel, 1908" (2) "2783"; 1 ♀ [no date] (1) "Cameroun, Batouri".

Tabanus sequax Wiliiston, 1887 as *Hybomitra sequax* (Willis.) – Canada: 1 ♀ (1) "2-VIII-1952 B.C. [British Columbia], Squamish | 3200 ft, Diamond Mead Trail | W.M.R Mason|"; 1 ♀ (1) "10-VI-1952 B.C. [British Columbia], Mt. Revelstoke | 5800 | G.J. Sperncer".

Tabanus silvanus Ricardo, 1908 *as Tabanus albitibialis* Surcouf – [Madagascar]: 1 ♀ (1) "1855/1919 Madagascar | Lasty Capt. | Grandidier" (2) "2997"; 1 ♂ (1) "21-VIII-1923 Rambonilld | F. Le Cerri" (2) "Museum Paris | Coll. J. Surcouf 1919 | *Tabanus sudeticus*?" (2) "2921".

Tabanus socialis = *Tabanus conformis* Walker, 1848.

Tabanus socius = *Tabanus taeniola* Palisot de Beauvois, 1807.

Tabanus solstitialis (Meigen, 1820) – France: 1 ♀ [no date] (1) "Lardy | (S.-&-P.) | J. Surcouf" (2) "Museum Paris | Coll. J. Surcouf 1919" (3) "2922".

Tabanus sorbillans Wiedemann, 1828 – Brazil: 2 ♀♀ (1) "V-1969 Barbalha [Ceará] | Alvarenga"; 1 ♀ (1) "VI-1951 Rio Grande do Norte | Natal | M. Alvarenga Col"; 2 ♀♀ (1) "XI-1972 Goiás | Jataí | F.M. Oliveira"; 1 ♀ (1) "IX-1972 Minas Gerais | Pedra Azul | Seabra & Oliveira"; as *Tabanus pseudosorbilans* – 1 ♀ [no data].

Tabanus spodopterus Meigen, 1820 – [Europe]: 2 ♀♀ [no date] both wit label (1) "Museum Paris | Coll. J. Surcouf 1919" (2) "2989" and (2) "2990", each one.

Tabanus striatus Fabricio, 1798 as *Tabanus strophiatus* Surcouf – India: 2 ♂♂ [no date] both with label (1) "Inde Meridionale | Trichinopoly | P. Caius 1911" (2) "2806" and (2) "2807", each one.

Tabanus strophiatus Surcouf = *Tabanus striatus* Fabricio, 1798.

Tabanus subangustus Ricardo, 1808 – [Sudan, West Africas]: 1 ♀ [no date] (1) "Museum Paris | Dahomey" (2) "2790".

Tabanus sudeticus Zeller, 1842 – France: 1 ♂ [no date] (1) "Museum Paris | Les Salles d'Ollone [Vendé] | Ma. Benoist Bazile 1931" (2) "2907". German: 1 ♀ [no date] (1) "Vogesenkamm Weiser See | 1200-1300 m | G. Bouvier, det. | *Tabanus sudeticus*" (2) "EMBRAPA".

Tabanus taeniola Palisot de Beauvois, 1807 as *Tabanus socius* – Tchad: 1 ♀ [no date] (1) "Museum Paris | Tchad | region de Lac Filtri | L. Lebras 1904" (2) "2817"; 1 ♀ 6-VI-1911 (1) "Cudo Gironde" (2) "Museum Paris | Coll. J. Surcouf" (3) "2588". Mozambique: 2 ♂♂ (1) "30-X-1925 [?]eire" (2) "Museum Paris | Mozambique | Nov. Chupanga | December-Janvier 1929 | J. Surcouf" (3) "2781" and "2907", each one.

Tabanus tarandinus = *Hybomitra tarandina* (Linnaeus, 1861).

Tabanus tergestinus Egger, 1859 as *Tabanus tergostigmus* Egg – France: 1 ♀ (1) "29-VI-1902 Nemours" (2) "Museum Paris | Coll. J. S urcouf 1919" (3) "2987".

Tabanus thoracinus Palisot de Beauvois, 1807 – Republic of Congo: 1 ♀ (1) "I-1904 Museum Paris | Congo Franç. |Mayumba | E. Brumpt 1906" (2) "2913"; 1 ♀ [no date] (1) "Museum Paris | Congo | Dybrowsky 1894" (2) "2914".

Tabanus triangulum Wiedemann, 1828 – Brazil: 1 ♀ (1) "21-X-1936 Goiás | Anápolis" (2) "205"; as *Tabanus triangulus* – 1 ♀ (1) "27-IX-1933 (2) 1.111 | J. Lane col".

Tabanus trivittatus Fabricius, 1805 – Brazil: 3 ♀♀ (1) "IX/X-1940 all with label Pará | Belém | Aurá | Mangabeira"; 1 ♀ (1) "20-II-1938 Amazonas | C.E.L.W.A."; 5 ♀♀ (1) "23-XI-1955 Amazonas | Manaus | Elias & Roppa"; 1 ♀ (1) "14-IV-1936 São Paulo | Ipiranga | *N. trivittatus* O. Castro Det | L. Moreti Col".

Tabanus tropicus = *Hybomitra tropica* (Linnaeus, 1758).

Tabanus unifasciatus Lowe 1858 – France: 1 ♂ (1) "22-VI-1942 Gallia | Champagne | Rhone | Emile Roman | Yeux a une band" (2) "3004".

Tabanus uniformis Ricardo, 1911 – India: 1 ♀ (1) "1921 Inde | region Hymalayense | Kursêono, 1500 m alt" (2) "Museum Paris | Inde | P. Caius 1921" (3) "2804".

Tabanus ustris Walker, 185 – Mozambique: 1 ♀ (1) "XII-1928/I-1929 "MUSEU PARIS | Moçambique | Nov Chupanga | J. Surcouf" (2) "2785".

Tabanus vittatus [unrecognizable name] – Spain: 2 ♀♀ (1) "1923/24 Museum Paris | Espagne | Peñaroya | A. Séryg, 1923-24" (2) "2967" and (2) "2968" each one specimen.

Tabanus wokei Fairchild, 1983 – Brazil: 1 ♀ (1) "XI-1943 P. Esperança a Murtinho | Bordo Mario | Mis. Cient. Brazil Col" (2) "A. L. Henriques det".

Tabanus yao Macquart, 1855 – Japan: 1 ♀ (1) "12-VI-1907" "Kumanotaira | pr. Karuizaura" (2) "Museum Paris | Nippon, Moyen | E. Galois 1912" (3) "2812".

Unidentified specimens of Genus *Tabanus*: 996

Discussion

There were 5,325 tabanids specimens in the collection and only 2,916 (54,76 %) were identified at species level, 2,409 at genera level and 192 (3,60 %) lack genera and species identification. All species identified at genus level belongged to neotropic genera, except those of genus *Therioplectes*. Many species were synonymized and the specific identification updated did not appear on the labels. But the collection was lost and nothing more can be done. The authors are solidirized with entomological researches of MNHN-RJ.

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Autor's Contributions

Ronald Rodrigues Guimarães: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Valéria Magalhães Aguiar: Substantial contribution in the concept and design of the study; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Inventory

Butterflies (Lepidoptera: Papilionoidea) from the campos rupestres of Serra de São José, Minas Gerais, Brazil

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Abstract: We provide the first inventory of butterfly species (Lepidoptera: Papilionoidea) in Serra de São José, Minas Gerais, Brazil. Serra de São José has elevations ranging from 800 m to 1,400 m above sea level; the butterflies were sampled using traps and entomological nets in seven plots along the altitudinal gradient. We recorded 647 butterflies belonging to 112 species and six families. We also recorded one threatened species and three endemic species for the Cerrado domain, which suggests that Serra de São José is an important refuge for butterfly conservation.
Keywords: *Cerrado, Conservation, Diversity, Inventory, Species richness, Threatened species.*

Borboletas (Lepidoptera: Papilionoidea) dos campos rupestres da Serra de São José, Minas Gerais, Brasil

Resumo: Fornecemos o primeiro levantamento de espécies de borboletas (Lepidoptera: Papilionoidea) da Serra de São José, Minas Gerais, Brazil. A Serra de São José possui elevações variando de 800 a 1.400 m de altitude, onde as borboletas foram amostradas utilizando armadilhas e redes entomológicas em sete áreas ao longo do gradiente altitudinal. Nós registramos 647 borboletas pertencentes a 112 espécies e seis famílias. Também registramos uma espécie ameaçada e três espécies endêmicas do Cerrado, o que sugere que a Serra de São José seja um importante refúgio para a conservação de borboletas.
Palavras-chave: *Cerrado, Conservação, Diversidade, Levantamento, Riqueza de espécies, Espécies ameaçadas.*

Introduction

Campos rupestres is a type of vegetation in high-altitude environments that covers rocky outcrops and is found most often in quartzite soil (Fernandes 2016). It occupies about 0.78% of the area in Brazil and its core area is along the Espinhaço Range (Silveira et al. 2016). Campos rupestres are recognized for their great biodiversity; their most striking aspects are the large number of endemic flora and fauna species they contain (Rapini et al. 2008, Fernandes et al. 2014). There is very little information about many insect groups, including butterflies, in several regions of Brazil (Freitas & Marini-Filho 2011, Soldati et al. 2019), and lepidopteran studies of campos rupestres remain scarce.

Brazil hosts more than 3,000 butterfly species, about 40% of the known richness of Neotropical butterflies — almost 8,000 species (Lamas 2008, CTFB 2018). Butterflies represent about 13% of Lepidoptera (Heppner 1991) and are separated into two large guilds according to feeding habits as adults: the frugivorous butterflies can feed on fruits, exudates, and plant sap and include more than 50% of Nymphalidae, whereas nectarivorous butterflies feed on nectar and are found in all families, including some species of Nymphalidae (DeVries et al. 1997). Their colors and shapes make them a charismatic group, attracting researchers and sensitizing the population to environmental conservation, and they can also be used as flagship species for ecosystem protection and biodiversity conservation plans (Guiney & Oberhauser 2008, Santos et al. 2011).

Butterflies are considered a suitable bioindicator taxa (Thomas 2005), as they have a short lifespan, can be easily sampled, and are sensitive to climatic variations, responding quickly to environmental changes (Freitas et al. 2003, Uehara-Prado et al. 2009, Francini et al. 2011). Moreover, several butterfly species are listed as endangered (IUCN 2016), and many species are considered rare, with only one (*singleton*) or two (*doubleton*) individuals sampled (Cowell 2004, Ferraz et al. 2009). Knowledge of local diversity is a fundamental ecological issue (Nobre et al. 2008), and species lists constructed with precise identification of organisms can be valuable for future studies. A species list can therefore aid the creation of conservation units and protected areas (Bustos 2008, Mielke et al. 2008) and provide basic data on distribution, abundance, and occurrence.

Biodiversity knowledge is the first step for formulating policies for preserving butterfly communities and for generating data to support future research (Dolibaina et al. 2011). Although species survey is encouraged, research on butterfly communities at altitudinal gradients and tropical mountains remains insufficient (Pires et al. 2018 and references therein), especially in campos rupestres. For the Campo das Vertentes mesoregion, where the Environmental Protection Area of Serra de São José is located in Minas Gerais state, data on the butterfly fauna remain nonexistent. Considering the lack of studies in the entire region, the aim of the present study was to provide the first list of butterfly species of the campos rupestres of Serra de São José, Minas Gerais, Brazil.

Material and Methods

1. *Study area*

The study was conducted inside Environmental Protection Area of Serra de São José, located in south-central Minas Gerais (21° 7' 8.87" S, 44° 7' 22.84" W, Figure 1). It belongs to the Serra da Mantiqueira system, but its vegetation and geological characteristics are quite similar to that of the Espinhaço Range (Oliveira-Filho & Machado 1993, Vasconcelos 2011). Serra de São José has elevations ranging from 800 m to 1,400 m above sea level, and exhibits phytophysiognomies of the Cerrado and Atlantic domains, with semideciduous seasonal forest and cerrado at its lower elevations, and campos rupestres at the highest elevations. It spans 4,758 ha (Cirino & Lima 2008) and the climate is marked by mild summers and winter droughts (Köppen classification: Cwb; Alvares et al. 2013). The average annual rainfall is about 1,500 mm; the average temperature ranges 19–20°C (Gonzaga et al. 2008).

2. *Data sampling*

Butterfly sampling was performed over a 1-year period (March 2016 to March 2017) over four seasons (Season 1: March and April 2016, Season 2: June and July 2016, Season 3: November and December 2016, Season 4: January, February, and March 2017) along seven altitudinal bands between 800 m and 1,413 m, with sampling at every 100 m of altitude. Van Someren–Rydon traps, separated by at least 50 m, were placed at all altitudinal bands to capture frugivorous butterflies. The traps remained in the field for 72 hours and were baited with a mixture of banana and molasses that had been fermented for 48 hours (Uehara-Prado et al. 2009, Santos et al. 2011). The trap effort totaled 864 hours. Net sampling was also performed at each altitudinal band during the same 1-year period, when the butterflies are most active, i.e., in the mornings and early afternoons (9 a.m. to 3 p.m., Santos et al. 2011, Silva et al. 2017). At each altitudinal band, net sampling was carried out for nearly five hours per day, totaling 155 effective hours in 28 sampling periods. The sampled butterflies were placed in entomological envelopes with descriptions of the altitude, and the date and time of collection. The butterflies were sacrificed, mounted, and later identified with the aid of field guides and/or specialists. The butterflies were organized into a reference collection deposited at the Entomological Collection of the Department of Natural Sciences of the Federal University of São João del-Rei (DCNat/UFSJ).

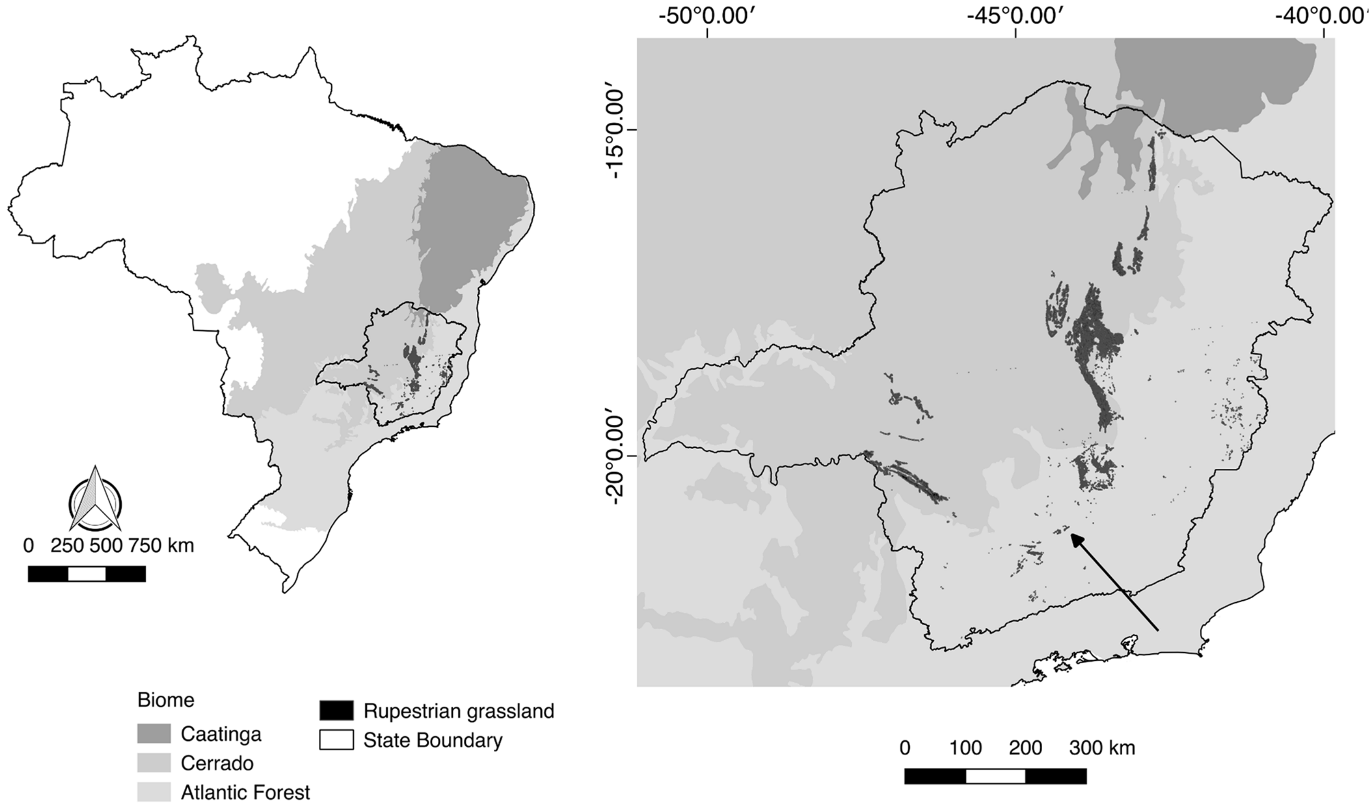

Figure 1. Map of the location of Serra de São José, Minas Gerais, Brazil.

3. Data analysis

To evaluate sampling efficiency, a rarefaction curve was built using the *specaccum* function in Vegan (Oksanen et al. 2015) in R software (R Core Team 2017); the rarefaction method was based on the sampling periods (7 bands × 4 seasons). To estimate butterfly diversity, three richness estimator indices (Jackknife 1, Chao 1, Bootstrap) were calculated using the *specpool* function in Vegan. Additionally, rare species were classified as *singleton* (one individual sampled) or *doubleton* (two individuals sampled) (Ferraz et al. 2009) to examine the species distribution frequency in the butterfly community.

Results

A total of 647 individual butterflies from 112 species belonging to 19 subfamilies were recorded in the campos rupestres of Serra de São José (Table 1). Nymphalidae (67 species, 58.04% of all species sampled) was the most speciose family, followed by Hesperiidae (18 species, 16.07%), Pieridae (11 species, 9.82%), Lycaenidae (7 species, 6.25%), Riodinidae (6 species, 5.36%), and Papilionidae (5 species, 4.46%). Nymphalidae was also the most abundant family, comprising more than 50% of all specimens sampled (327 individuals, 50.5% of the total recorded), followed by Hesperiidae (N = 140, 21.6%), Pieridae (N = 116, 17.9%), Lycaenidae (N = 39, 6.0%), Papilionidae (N = 16, 2.5%), and Riodinidae (N = 11, 1.7%). The most abundant species were *Pyrisitia nise tenella* (Pieridae: Coliadinae, N = 46), *Urbanus teleus* (Hesperiidae: Eudaminae, N = 44), *Actinote thalia pyrrha* (Nymphalidae: Heliconiinae, N = 36), and *Pharneuptychia pharnabazos* (Nymphalidae: Satyrinae, N = 27). Together, these four species represented 24% of all butterflies sampled. Only two species occurred at all seven altitudinal bands: *Actinote genitrix genitrix* (Nymphalidae: Heliconiinae) and *Pyrisitia nise tenella* (Pieridae: Coliadinae). We found three endemic Cerrado species (following Pinheiro et al. 2010): *Parides bunichus diodorus* (Papilionidae: Papilioninae), *Sophista latifasciata latifasciata* (Hesperiidae: Pyrginae), and *Yphthimoides straminea* (Nymphalidae: Satyrinae), and we registered one species listed in the Brazilian Red List: *Actinote zikani* (Nymphalidae: Heliconiinae).

Despite our sampling efforts, the species–rarefaction curve did not reveal any asymptote tendency (Figure 2). Jackknife 1 predicted that there would be 155 species, i.e., 43 species additional to those sampled in this study; Chao 1 and Bootstrap estimated 156 and 132 species, respectively. Of the 327 butterflies recorded for Nymphalidae, only 37 individuals were sampled in traps, and five species were caught exclusively in traps: *Callicore sorana sorana* (Biblidinae), *Caligo brasiliensis brasiliensis* (Satyrinae), *Fountainea ryphea phidile* (Charaxinae), *Taygetis laches* (Satyrinae), and *Temenis laothoe meridionalis* (Biblidinae). We recorded 36 species with only a single individual (*singletons*) and 21 species with only two individuals (*doubletons*), indicating that half of the sampled butterfly species are rare.

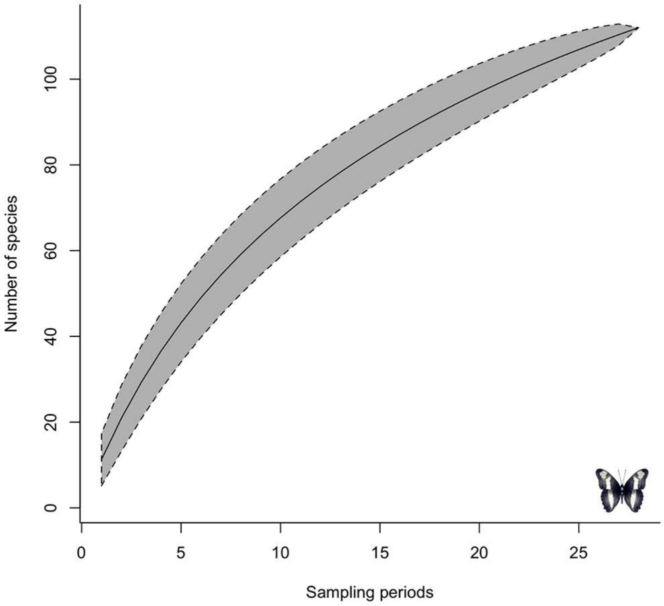

Figure 2. Rarefaction curve based on sampling period of butterfly species in Serra de São José, Minas Gerais, Brazil. Error bars indicate 95% confidence intervals.

Discussion

The richness of butterfly species on Serra de São José is within the expected range for the campos rupestres, although it is higher than that observed in other inventories for the Brazilian Cerrado and open grassy vegetation (e.g., Bogiani et al. 2012, Araújo & Paprocki 2015, Fernandes et al. 2016, Martins et al. 2017). For example, Nery et al. (2014) used the same two sampling methods and found 60 species in Serra do Intendente, Minas Gerais — a 13.447 ha area — which is much larger than Serra de São José. Pires et al. (2018) found 172 species in Serra do Cipó, Minas Gerais, an area similar in altitude and vegetation type to Serra de São José, but a much greater area (almost 34.000 ha) and with greater sampling effort (the present study versus Pires et al. 2018: net, 155 hours versus 336 hours; bait trap, 36 days versus 252 days).

Comparing the present species list to that of Nery et al. (2014) and Pires et al. (2018), the two closest mountain regions to Serra de São José with published inventories, we found 20 shared species with Serra do Intendente (Nery et al. 2014) and 39 shared species with Serra do Cipó (Pires et al. 2018). In addition, 16 species are found in all three mountains (Table 1). The large number of species shared with Serra do Cipó was expected due to the greater number of species listed and because it is a campos rupestres area (*sensu* Silveira et al. 2016) extremely similar to Serra de São José. Despite this, there was only 23% shared species, demonstrating that several butterfly species are exclusive to each region.

Even in small habitats, it is extremely difficult to estimate the total richness of organisms, especially in the case of insects, a megadiverse group (Beutel et al. 2017). According to the Jackknife 1 estimator, 72.3% of the species pool was sampled at Serra de São José, higher compared to the 66–68% found by Pereira et al. (2017)

Table 1. List of butterfly species from Serra de São José, Minas Gerais, Brazil. S = number of species; * = shared species with Serra do Intendente, Minas Gerais (Nery et al. 2014); • = shared species with Serra do Cipó, Minas Gerais (Pires et al. 2018).

Species	Abundance
HESPERIIDAE (S = 18)	
Eudaminae (S = 4)	
Pseudonascus paulliniae (Sepp, [1842])	2
Urbanus evenus (Ménetriés, 1855) •	2
Urbanus proteus proteus (Linnaeus, 1758)	14
Urbanus teleus (Hübner, 1821)	44
Hesperiinae (S = 4)	
Argon lota (Hewitson, 1877)	10
Hylephila phyleus phyleus (Drury, 1773) •	2
Polites vibex catilina (Plötz, 1886) •	2
Vettius artona (Hewitson, 1868)	3
Pyrginae (S = 10)	
Chiomara asychis autander (Mabille, 1891)	3
Heliopetes alana (Reakirt, 1868)	17
Heliopetes arsalte arsalte (Linnaeus, 1758) •	1
Heliopetes omrina (A. Butler, 1870) * •	12
Pyrgus orcus (Stoll, 1780) * •	14
Pyrgus orcynoides (Giacomelli, 1928)	1
Sarbia damippe Mabille & Boullet, 1908	2
Sophista latifasciata latifasciata (Spitz, 1930) •	1
Staphylus chlorocephala (Latreille, [1824])	6
Timochares trifasciata trifasciata (Hewitson, 1868)	2
LYCAENIDAE (S = 7)	
Polyommatinae (S = 2)	
Hemiargus hanno hanno (Stoll, 1790) •	22
Leptotes cassius cassius (Crammer, 1775) * •	4
Theclinae (S = 5)	
Arawacus tarania (Hewitson, 1868) •	7
Contrafacia imma (Prittwitz, 1865)	1
Ministrymon cruenta (Gosse, 1880)	1
Strymon mulucha (Hewitson, 1867) •	2
Tmolus echion (Linnaeus, 1767)	2
NYMPHALIDAE (S = 65)	
Biblidinae (S = 9)	
Callicore sorana sorana (Godart, [1824]) * •	3
Dynamine agacles agacles (Dalman, 1823)	1
Ectima thecla thecla (Fabricius, 1796)	1
Hamadryas chloe rhea (Fruhstorfer, 1907)	2
Hamadryas epinome (C. Felder & R. Felder, 1867)	1
Hamadryas februa februa (Hübner, [1823]) * •	4
Hamadryas feronia feronia (Linnaeus, 1758) * •	1
Temenis laothoe meridionalis Ebert, 1965 * •	1
Myscelia orsis (Drury, 1782)	1
Charaxinae (S = 1)	
Fountainea ryphea phidile (Geyer, 1837)	2

continuation...

Species	Abundance
Danainae (S = 8)	
Aeria olena olena Weymer, 1875	5
Danaus eresimus plexaure (Godart, 1819)	2
Episcada hymenaea hymenaea (Prittwitz, 1865)	7
Hypothyris euclea laphria (E. Doubleday, 1847)	3
Mcclungia cymo salonina (Hewitson, 1855)	1
Mechanitis polymnia casabranca Haensch, 1905	3
Methona themisto themisto (Hübner, 1818)	3
Pseudoscada erruca (Hewitson, 1855)	11
Heliconiinae (S = 12)	
Actinote carycina Jordan, 1913	1
Actinote genitrix genitrix R.F. d'Almeida, 1922	21
Actinote melanisans Oberthür, 1917	18
Actinote surima surima (Schaus, 1902)	24
Actinote thalia pyrrha (Fabricius, 1775)	36
Actinote zikani R.F. d'Almeida, 1951	1
Agraulis vanillae maculosa (Stichel, [1908])	4
Dione juno juno (Cramer, 1779)	1
Dryas iulia alcionea (Cramer, 1779) *	8
Eueides pavana Ménétriés, 1857	1
Heliconius erato phyllis (Fabricius, 1775) * •	13
Heliconius ethilla narcaea (Godart, 1819) * •	5
Libytheinae (S=1)	
Libytheana carinenta carinenta (Cramer, 1777)	3
Limenitidinae (S = 3)	
Adelpha abia (Hewitson, 1850)	3
Adelpha lycorias lycorias (Godart, [1824])	1
Adelpha syma (Godart, [1824])	2
Nymphalinae (S = 7)	
Anartia amathea roeselia (Eschscholtz, 1821) *	3
Anartia jatrophae jatrophae (Linnaeus, 1763) •	5
Eresia lansdorfi (Godart, 1819) * •	1
Historis odius dious Lamas, 1995	1
Junonia evarete evarete (Cramer, 1779) * •	18
Tegosa claudina (Eschscholtz, 1821)	14
Vanessa braziliensis (Moore, 1883) •	6
Satyrinae (S = 24)	
Caligo brasiliensis brasiliensis (C. Felder, 1862) •	2
Carminda paeon (Godart, [1824])	1
Hermeuptychia sp.	1
Moneuptychia giffordi A.V.L. Freitas, Emery & O.H.H. Mielke, 2010	1
Moneuptychia melchiades (A. Butler, 1877)	1
Morpho anaxibia (Esper, [1801])	1
Morpho epistrophus catenaria Perry, 1811	2
Morpho helenor achillaena (Hübner,[1823]) * •	1

continuation...

Species	Abundance
Opsiphanes invirae pseudophilon Fruhstorfer, 1907 •	3
Pareuptychia ocirrhoe ocirrhoe (Fabricius, 1776) *	1
Paryphthimoides eous (A. Butler, 1867)	6
Paryphthimoides poltys (Prittwitz, 1865)	2
Paryphthimoides zeredatha (A. Butler, 1869)	2
Pharneuptychia innocentia (C. Felder & R. Felder, 1867)	2
Pharneuptychia phares (Godart, [1824]) •	4
Pharneuptychia pharnabazos (Bryk, 1953)	27
Taygetis laches Fabricius, 1793 * •	3
Yphthimoides affinis (A. Butler, 1867) •	2
Yphthimoides borasta (Schaus, 1902)	5
Yphthimoides manasses (C. Felder & R. Felder, 1867)	1
Yphthimoides mimula (Hayward, 1954)	1
Yphthimoides patricia (Hayward, 1957) •	3
Yphthimoides renata (Stoll, 1780) •	5
Yphthimoides straminea (A. Butler, 1867) *	8
PAPILIONIDAE (S = 5)	
Papilioninae (S = 5)	
Heraclides anchisiades capys (Hübner, [1809])	1
Heraclides pallas (G. Gray, [1853])	1
Heraclides thoas brasiliensis (Rothschild & Jordan, 1906) •	8
Parides bunichus diodorus (Hopffer, 1865) •	4
Protesilaus helios (Rothschild & Jordan, 1906)	2
PIERIDAE (S = 11)	
Coliadinae (S = 6)	
Aphrissa statira statira (Cramer, 1777)	2
Eurema albula sinoe (Godart, 1819) * •	14
Eurema elathea flavescens (Chavannes, 1850) * •	20
Phoebis philea philea (Linnaeus, 1763)	2
Phoebis sennae sennae (Linnaeus, 1758) •	19
Pyrisitia nise tenella (Boisduval, 1836) •	46
Dismorphiinae (S = 1)	
Pseudopieris nehemia nehemia (Boisduval, 1836)	
Pierinae (S = 4)	
Ascia monuste orseis (Godart, 1819) * •	4
Glutophrissa drusilla drusilla (Cramer, 1777) •	5
Hesperocharis anguitia anguitia (Godart, 1819) •	1
Pereute antodyca (Boisduval, 1836)	1
RIODINIDAE (S = 6)	
Euselasiinae (S = 1)	
Euselasia thucydides thucydides (Fabricius, 1793)	1
Riodininae (S = 5)	
Chalodeta lypera (H. Bates, 1868)	1
Emesis russula Stichel, 1910	4
Emesis sp.	1
Lemonias zygia zygia Hübner, [1807]	3
Synargis calyce brennus (Stichel, 1910) •	1

in Serra do Cipó and by Silva et al. (2015) in a Special Protection Area of Nova Lima (Minas Gerais), respectively. Bogiani et al. (2012) found 81% of the species estimated by Jackknife 1 in a Cerrado urban area, although only 60 species were recorded using the same two sampling methods and a very similar effort–hour to our study. The species richness estimated for Serra de São José indicates that the area, although smaller, might surpass the butterfly biodiversity of other campos rupestres areas.

Nymphalidae and Hesperiidae were the most represented families in our survey, a pattern already described and expected, as these two families, together with Lycaenidae, are among the families with the greatest species richness in Brazil (Bonfantti et al. 2009). In the present study, Nymphalidae exhibited the highest species richness and the greatest abundance. The family Nymphalidae has the greatest diversity of forms and behaviors and has nearly 800 species registered in Brazil (Silva et al. 2015, Ribeiro et al. 2016). Hesperiidae, in turn, is found in hilltops and open areas. It is very abundant in the high-altitude regions of southeastern Brazil, where many endemic species are found, and with high endemism in the Neotropical regions (Iserhard & Romanowski 2004, Carneiro et al. 2014, Pires et al. 2018).

The International Union for Conservation of Nature (IUCN) Red List describes the species conservation status in several categories, and the threatened species are grouped into three categories: vulnerable, endangered, and critically endangered (IUCN 2016). One butterfly species recorded in Serra de São José is listed in the Brazilian Red List as critically endangered (CR), the highest risk category among the threatened species: *Actinote zikani* (Nymphalidae: Heliconiinae). Despite the difficulty in accurately identifying which species are endemic to certain habitats, Pinheiro et al. (2010) presented a list of endemic butterflies of the Cerrado domain. Three species found in Serra de São José appear in this list: *Parides bunichus diodorus* (Papilionidae: Papilioninae), *Sophista latifasciata latifasciata* (Hesperiidae: Pyrginae) and *Yphthimoides straminea* (Nymphalidae: Satyrinae). The conservation of these endangered and endemic species in this mountain can be important for their preservation at regional and/or national level.

The campos rupestres is a mountaintop vegetation occurring exclusively in Brazil that harbors a great biodiversity of both plants and animals. It is a very important area for conservation aiming to preserve the high number of endemic species and their populations (Alves et al. 2014, Silveira et al. 2016). The butterfly fauna of campos rupestres remain poorly documented. In the last few years, new butterfly species of campos rupestres have been described (e.g., *Yphthimoides bella* and *Y. iserhardi* in Barbosa et al. 2015, *Nhambikuara cerradensis* in Freitas et al. 2018), showing the importance of research in this habitat and thereby emphasizing the importance of campos rupestres for butterfly biodiversity. Our study reveals that the campos rupestres of Serra de São José exhibits a diverse butterfly community and we aim to contribute to the knowledge of high-altitude butterflies in the region and for tropical mountains of campos rupestres, thereby providing the first inventory for the region. The large number of rare species found in this mountain, together with the endemic and threatened species recorded, suggests that this is an important area for butterfly conservation, and it deserves attention.

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Author contributions

Nathália Ribeiro Henriques: Contribution in the concept and design of the study; Contribution to data collection; Contribution to butterfly identification; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision.

Marina do Vale Beirão: Contribution to butterfly identification; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision.

Ello Brasil: Contribution in the concept and design of the study; Contribution to data collection.

Tatiana Cornelissen: Contribution in the concept and design of the study; Contribution to manuscript preparation; Contribution to critical revision.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Short communication

Morphometric characterization of *Dinophysis acuminata*/*D. sacculus* complex in Guanabara Bay, Brazil

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Abstract: Most studies of *Dinophysis acuminata* in Brazil are for the southern region, where blooms are recurrent. In 2016, the presence of *D. acuminata* caused the first-ever production and consumption of species of mollusks commercial embargo from the state of Sao Paulo, Southeast Brazil. Potentially toxic species of *Dinophysis* have been reported in Guanabara Bay (GB) but only occasionally and in low densities. The present note is the first report of a high-density event (~10^5 cells L^{-1}) of *D. acuminata*/*D. sacculus* complex in GB. *D. acuminata*/*D. sacculus* complex species were identified using scanning-electron and inverted-light microscopy. Most of the studied cells possessed a dorsally convex hyposomal plate and had dimensions typical of *D. acuminata*. However, the observed association with warmer and less saline estuarine waters would indicate that the species could be *D. sacculus*. Whatever the case, based on the high cell densities observed here, we recommend a continued monitoring for *Dinophysis* presence in GB.

Keywords: *dinoflagellates, Dinophysis acuminata, Dinophysis sacculus, eutrophic marine ecosystem, South Atlantic Central Water*

Caracterização morfométrica de dinoflagelados do Complexo *Dinophysis acuminata*/*D. saculus* na Baía de Guanabara, Brasil

Resumo: A maioria dos estudos sobre *Dinophysis* acuminata no Brasil ocorreram na região sul, onde as florações são recorrentes. Em 2016, a presença de *D. acuminata* causou o primeiro embargo comercial da produção e consumo de espécies de moluscos do estado de São Paulo, sudeste do Brasil. Várias espécies de microalgas potencialmente nocivas foram relatadas na Baía de Guanabara (BG), incluindo espécies tóxicas de *Dinophysis*, mas estas foram reportadas apenas como ocasionais e em baixas densidades. A presente nota é o primeiro relato de um evento de alta densidade (~ 10^5 células L^{-1}) do complexo *D. acuminata*/*D. saculus* na BG. As espécies foram identificadas através de microscopia eletrônica de varredura e de campo claro. A maioria das células estudadas possuía uma placa hipossômica dorsalmente convexa, e tinha dimensões típicas de *D. acuminata*. No entanto, a associação observada com águas estuarinas mais quentes e menos salinas indicaria que a espécie seria *D. saculus*. Qualquer que seja o caso, com base nas altas densidades observadas aqui, recomendamos o monitoramento contínuo da presença de *Dinophysis* na BG.

Palavras-chave: *dinoflagelados, Dinophysis acuminata, Dinophysis saculus, ecossistema marinho eutrófico, Água Central do Atlântico Sul.*

Introduction

The genus *Dinophysis* Ehrenberg includes species with a diverse morphology and different trophic strategies (autotrophic, heterotrophic and mixotrophic) (Zingone et al. 1998). Some of these species are potential producers of phytotoxin and can be responsible for human intoxication events, even in densities as low as $<10^2$ cells·L^{-1}, which are rarely detected by quantitative methods (Reguera et al. 2012). *Dinophysis acuminata* Claparède & Lachmann (Hattenrath-Lehmann et al. 2015) has received significant attention because inputs of nutrients and organic matter can promote both its toxicity and growth. Nevertheless, this species belongs to the "*D. acuminata* complex", which contains taxa that are difficult to discriminate with conventional microscopy due to morphological variability (Reguera et al. 2012). One such case is the pair *D. acuminata* Claparède & Lachmann/*D. sacculus* F. Stein (Zingone et al. 1998), which can co-occur (Reguera et al. 2012). Both species have been associated with diarrhetic shellfish poisoning (DSP) events (Reguera et al. 2012, and references, García-Altares et al. 2016).

In Brazil, most of the studies on *D. acuminata* have occurred in the South region, due to its great importance for oyster and mussel cultivation. (Mafra-Junior et al. 2006, Mello et al. 2010, Simões et al. 2014, Tibiriçá et al. 2015). Natural blooms of this species along the southern Brazilian coast lead to recurrent commercial embargos of cultivated species, resulting in important economic losses (Simões et al. 2014). From May to July 2016, *D. acuminata* was reported along the coast from Santa Catarina to São Paulo in densities that led to the first-ever commercial embargo of the production and consumption of oysters and mussels by the health authorities of the state of São Paulo (A Tribuna 2016).

Although *D. acuminata* has been detected along Rio de Janeiro's coast, blooms have not been reported yet. At Sepetiba Bay on the southern coast of Rio de Janeiro, *D. acuminata* was found to be dominant among the five species of the genus detected, but both cell densities and toxin concentrations on mussels were lower than the limit allowed by law (Ferreira et al. 2010, Brasil 2012). Guanabara Bay (GB) encompasses many more municipalities than the city of Rio de Janeiro, being the second largest bay of the Brazilian coast, and is historically under intense eutrophication, thus a program of continuous monitoring of planktonic species should be implemented (Fistarol et al. 2015). Several potentially harmful microalgal species have been reported at high densities in GB: *Scrippsiella trochoidea* (Stein) Loeblich (Villac & Tenenbaum 2010), *Pseudo-nitzschia* H. Peragallo spp. (Rezende et al. 2015), filamentous cyanobacteria, *Prorocentrum* Ehrenberg spp. (Villac & Tenenbaum, 2010, Rezende et al. 2015), and *Chattonella* B.Biecheler spp. (Fistarol et al. 2015). The potentially toxic species of the genus *Dinophysis* (i.e. *D. acuminata/ D. sacculus)*, however, have been described as only occasional and in low densities (Rezende et al. 2015). Nonetheless, several studies have recommended the implementation of protocols able to detect *Dinophysis* sp. at low-densities ($<10^2$ cells L^{-1}) in the water column serving as an early warning system (Reguera et al. 2014).

The present work is the first report of a bloom of *Dinophysis* in Guanabara Bay, Rio de Janeiro (Brazil), and a morphological and morphometric study of the analyzed cells is provided.

Material and Methods

Surveys were performed on September 1st, 2015, along a transect of eight sampling points from Paquetá Island (inner region) to Rasa Island (outer region) along the dredged channel of Guanabara Bay (22°80'S; 43°14'W) (Figure 1). Phytoplankton samples were collected, both during ebb and during flood tides, with Niskin bottles at sub-surface and near the bottom. Sub-samples of 250 mL were fixed with Lugol´s solution and preserved in the dark, at room temperature, until laboratory analysis. At laboratory, aliquots of 5 – 10 mL were prepared according to the Utermölh (1958) method and examined and photographed under 200 x and 400 x magnification using a ZEISS® Axiovert A1 inverted microscope and an ZEISS® AxioCAM 105 camera. Bright field (BF) and phase contrast (PH) were used for identification. Images of the different organisms identified were captured with the AxioCAM 105 camera and processed with the software Zen (Blue Edition; Carl ZEISS®). The images of 55 organisms were used to measure the morphological parameters (length, width and the hidden dimension) of the cells of *D. acuminata/D. sacculus* complex. Cell surface and cell volume were calculated according with the equations described in Sun & Liu (2003). Samples were prepared for scanning electron microscopy (SEM) by gentle filtration of 20 ml through 0.2 µm pore-size Nuclepore membranes. Salt was removed by washing the filters with small amounts of deionized water. The filters were dried, mounted on stubs with double-sided sticky tape and vacuum coated with graphite. The samples were examined with a JEOL JSM 6510LV scanning electron microscope.

The relationships among phytoplanktonic cell densities and abiotic variables were determined using Pearson's correlation (Software Statistica® by Statsoft) (Cassie, 1962).

Results

Water temperature was higher in the inner region (19.9 – 25.1 °C) than in the outer region (16.1 – 19.8 °C) of the bay. Salinity ranged from 24.2 to 35.2 in the inner region, and from 35.3 to 36.0 in the outer. Total chlorophyll ranged from 2.04 to 45.03 mg m^{-3} in the inner region, and from 0.45 to 7.48 mg m^{-3} in the outer.

Phytoplankton densities were higher in the inner region (2.8×10^5 – 2.8×10^7 cells L^{-1}) than in the outer region (5.1×10^3 – 4.1×10^6 cells L^{-1}). Although they were not dominant, dinoflagellate densities ranged from 1.3×10^4 – 2.2×10^6 cells L^{-1} to 4.0×10^1 – 3.9×10^5 cells L^{-1}, in the inner and outer regions, respectively. Among the dinoflagellates, the genus *Prorocentum* was dominant (average > 50 %), both in the inner and outer regions. The contribution of the genus *Dinophysis* was lower than 10% on average (maximum 25%), with the *D. acuminata*/*D. sacculus* complex being dominant for this genus (maximum 1.2×10^5 cells L^{-1} at inner portion) (Table 1). The cell density of the *D. acuminata*/*D. sacculus* complex was positively correlated with that of *P. dentatum* ($r=0.91$; $p<0.001$) and *P. micans* ($r=0.79$; $p<0.01$). The abundance of *D. acuminata/D. sacculus* complex was also positively correlated ($r= 0.72$; $p<0.001$) with temperature and negatively correlated ($r= -0.61$; $p<0.001$) with salinity.

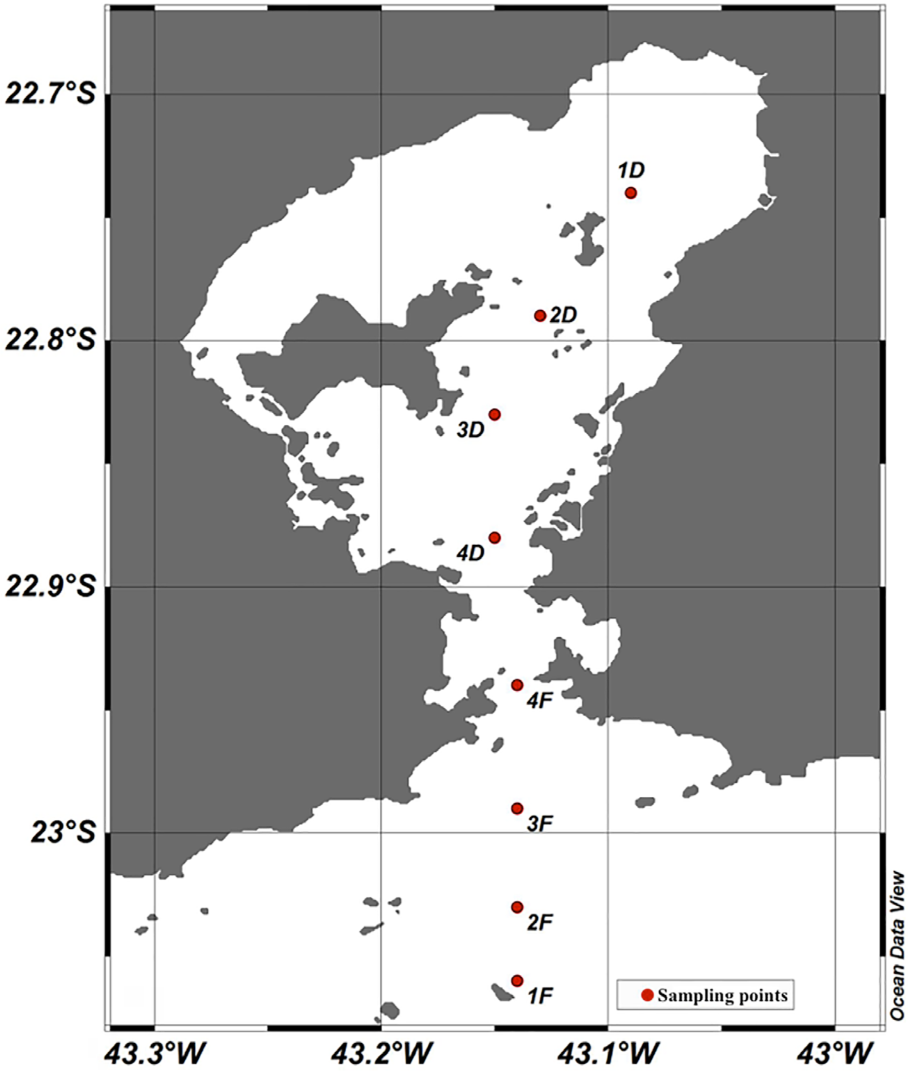

Figure 1. Study area - Guanabara Bay (Rio de Janeiro, Brazil). Sampling points (red dots) in a transect from the inner part of the bay (denoted by a number and letter D) to the inner continental shelf (denoted by a number and letter F).

Table 1. Average (av.), standard deviation (sd), minimum (min) and maximum (max) of cell densities (x10^3 cells L^{-1}) of *Dinophysis genera*, *Dinophysis acuminata*/*sacculus* complex, and Prorocentrum genera at inner and outer regions.

Region		***Dinophysis acuminata/ sacculus* complex**	***Prorocentrum micans***	***Prorocentrum dentatum***
inner	av.	22.57	210.84	339.73
	sd	29.34	332.52	330.74
	min	1.40	0.40	3.40
	max	115.55	1021.91	837.75
outer	av.	0.77	5.17	10.48
	sd	0.97	12.51	16.07
	min	0.00	0.00	0.00
	max	3.00	43.00	50.20

Cells of the *Dinophysis acumitata/D. sacculus* complex were 33.2 – 44.2 µm long, 20.3 – 32.3 µm wide, and 13.5 – 20.1 µm of hidden dimension (Table 2). The length/width (l/w) ratio varied from 1.2 to 1.9 and the Surface/Volume ratio ranged from 0.24 to 0.28. The shape of the cells was slightly convex, with a convex and sculptured sulcal platelet with three ribs, which was almost half of the hypothecal length (Figure 2a-g); this morphotype is intermediate between the two species of this complex.

Under SEM, small smooth pores were seen irregularly scattered on the surface of the hypotheca (Figure 2a). The number of pores distributed along 10 µm varies from six in the middle region of the hypotheca, to 12 near the cingular platelet (Figure 3a-b). Two rows of pores were observed on the sulcal platelet (Figure 3c).

Table 2. Average (av.), standard deviation (sd, minimum (min) and maximum (max) length, width, hidden dimension, length/width (l/w) ratio, surface (S), volume (V) and S/V ratio for the *Dinophysis acuminata*/*D. sacculus* complex at September 2015 (n=55).

***Dinophysis acuminata*/*D. sacculus* complex metrics**				
	av.	**sd**	**min**	**max**
length (μm)	38.8	1.9	33.2	44.2
width (μm)	25.1	2.7	20.3	32.3
hidden dimension (μm)	16.9	2.4	13.5	20.1
l/w ratio	1.56	0.14	1.17	1.90
S (μm^2)	2226	229	1709	2812
V (μm^3)	8648	1188	6085	11651
S/V	0.26	0.01	0.24	0.28

Discussion

During the winter of 2015, a high-abundance (~10^5-10^6 cells L^{-1}) event of dinoflagellates was observed at Guanabara Bay (Rio de Janeiro, Brazil). It was dominated by the genus *Prorocentrum* Ehrenberg, mainly the species *P. dentatum* F.Stein and *P. micans* Ehrenberg. Associated with these, the high cell densities of the *Dinophysis acuminata*/*D. sacculus* complex were also observed. The co-occurrence of *Dinophysis* and *Prorocentrum* blooms were previously reported by several studies (i.e. Reguera et al. 2012, Hattenrath-Lehmann et al. 2015), as well as the occurrence of a bloom of *Prorocentrum* after *Dinophysis* events (Campbell et al. 2010). *Prorocentrum micans*, which reached densities as high as 10^6 cells L^{-1} in the present work, was reported as highly abundant in warm and nutrient-rich waters, such as that of GB (Sahraoui et al. 2013). *Prorocentrum micans* was also reported as a producer of putative palytoxin and ovatoxin-a (Ignatiades & Gotsis-Skretas 2010), nevertheless, the frequent association of this species with DSP could be due to the presence of *D. acuminata* in densities too low to be detected (Reguera et al. 2014 and references therein).

Although *D. acuminata* is usually associated with colder waters and *D. sacculus* with warmer waters, the two species were reported coexisting in several coastal environments, probably due to the difficulty in distinguishing their cells (Zingone et al. 1998). Thus, in GB, the *Dinophysis* complex was clearly associated with the warmer and less saline waters of the inner estuary. In a study in southern Brazil, Haraguchi and Odebrecht (2010) reported high abundances of *D. acuminata* (~10^4 cells L^{-1}) associated with intrusions of a cold and salty water mass, the South Atlantic Central Water (SACW), while other species of *Dinophysis*, such as *D. fortii* Pavillard, were associated with warmer waters. In the present work, the influence of the SACW was especially observed in the outer region of GB (*data not published*), where lower densities of the *D. acuminata/D. sacculus* complex were observed, suggesting that most of the cells identified were probably *D. sacculus*.

Based on morphometric characteristics, most of the cells identified here possess a more dorsally-convex hypothecal plate with dimensions (especially the ratio l/w) typical of *D. acuminata*, and even the length of the cells found here is considerably shorter than those described in the

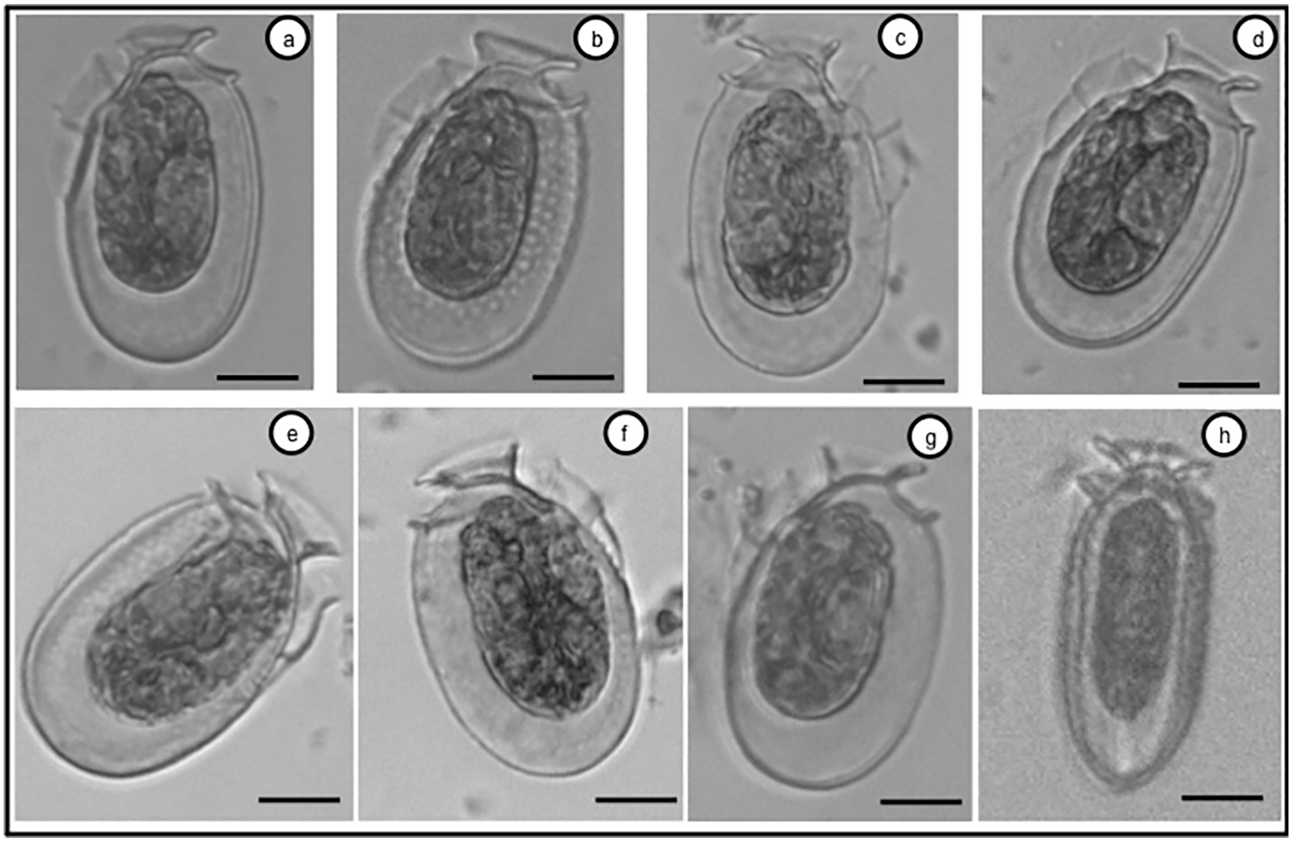

Figure 2. Lateral view (a-g) and hidden dimension (h) view of complete cells at Light Microscopy (LM) of *Dinophysis acuminata*/*D. sacculus* complex from Guanabara Bay samples. Scale bars: 10 μm.

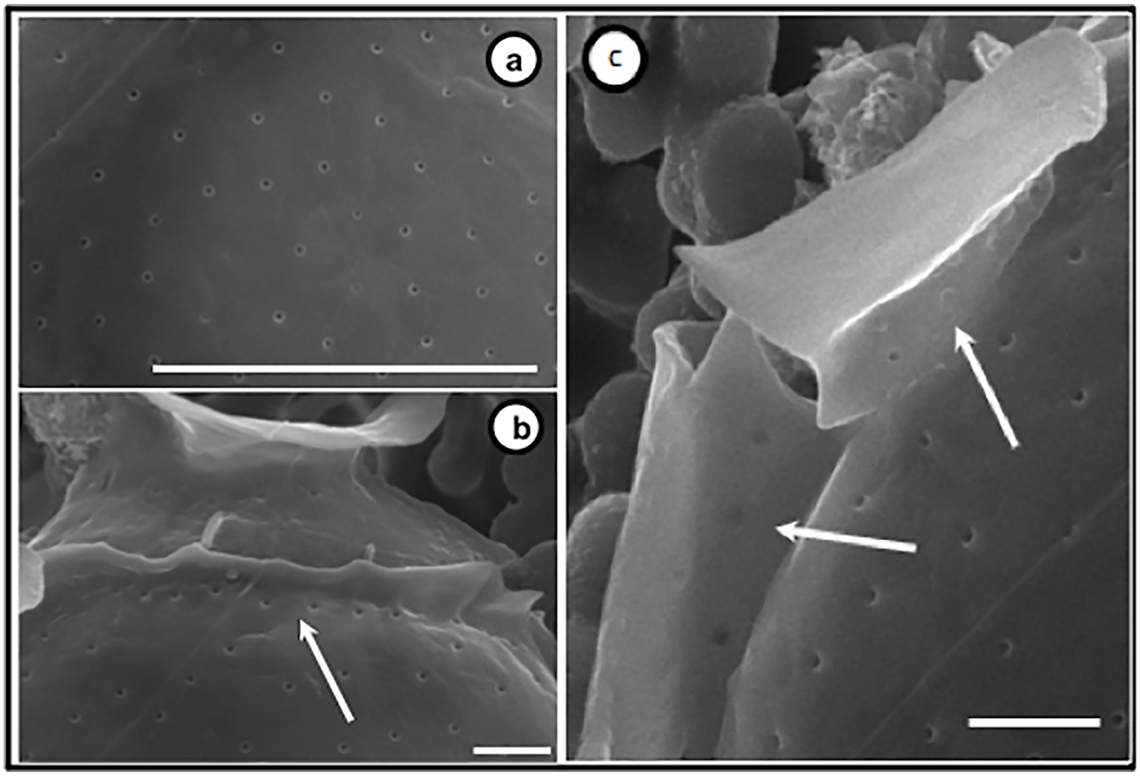

Figure 3. Details of the theca, scanning electron microscopy (SEM), of the cells of *Dinophysis acuminata*/*D. sacculus* complex from Guanabara Bay samples. Scale bars: a 10 µm; b-c 2 µm. Arrows indicate pores distribution.

literature (Zingone et al. 1998). On the other hand, the association with warmer and less saline estuarine waters was reported more often for *D. sacculus* than for *D. acuminata*, the latter being typical of colder waters. Nevertheless, both species of this complex were reported as potentially toxic even in low densities, as is the case for *D acuminata* (Zingone et al. 1998, Reguera et al. 2012, Reguera et al. 2014). In addition, nutrient loading can enhance both growth and toxicity of *Dinophysis* species (Hattenrath-Lehmann et al. 2015).

Thus, even without the ability to distinguish between the two species of the *D. acuminata/D. sacculus* complex, high densities of this complex would be monitored in highly eutrophic coastal areas, such as Guanabara Bay.

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Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Author Contributions

José Juan Barrera-Alba: substantial contribution in the concept and design of the study, contributed also to data analyses and manuscript preparation.

Fernanda Reinhardt Piedras: substantial contribution in the concept and design of the study, contributed also to data analyses and manuscript preparation.

Gleyci Aparecida Oliveira Moser: substantial contribution in the concept and design of the study, contributed also to data analyses and manuscript preparation.

Carla Lucatelli Duarte: contributed to data analysis and interpretation.

Raquel Neves Tavares Lopes: contributed to data analysis and interpretation.

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Article

Quadrigyrus torquatus cystacants Van Cleave, 1920 (Acanthocephala: Quadrigyridae) parasitizing species of *Astyanax* (Characiformes: Characidae) from southern Brazil

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GALLAS, M., UTZ, L. R. P. ***Quadrigyrus torquatus* cystacants Van Cleave, 1920 (Acanthocephala: Quadrigyridae) parasitizing species of *Astyanax* (Characiformes: Characidae) from southern Brazil.** Biota Neotropica. 19(3): e20180693. http://dx.doi.org/10.1590/1676-0611-BN-2018-0693

Abstract: The acanthocephalan species *Quadrigyrus torquatus* Van Cleave, 1920 has been found in different hosts from South America, but recent papers have not focused on its morphology traits. Different species of *Astyanax* Baird & Girard, 1854 were collected with seine nets between January 2017 and October 2017 in Pintada Island, Lake Guaíba, Porto Alegre city (30º17'11"S and 51º18'01"W), Rio Grande do Sul State, Brazil. Acanthocephalans found in cysts were processed according to the techniques for the group. Specimens of *Q. torquatus* were identified based mainly in the morphology of proboscis hooks and trunk spines, and by the measurements made using light microscopy. Supplemental observations on the morphology of *Q. torquatus* were made for the first time considering the morphology and amount of hooks and spines. The amplitude of intensity of infections was 1 (*A.* aff. *fasciatus*) and 1–3 (*A. lacustris*) helminths. This difference could be related to the number of hosts examined, the feeding habit of the hosts or related to aspects in the parasite life cycle. This paper is the first report of *Q. torquatus* in *A.* aff. *fasciatus* and *A. lacustris* from Lake Guaíba, extending the distribution to the southernmost state of Brazil, thus contributing to the knowledge of acanthocephalans in freshwater fishes from South America.
Keywords: *Acanthocephalan, helminths, endoparasite, taxonomy, Neotropical region.*

Cistacantos de *Quadrigyrus torquatus* Van Cleave, 1920 (Acanthocephala: Quadrigyridae) parasitando espécies de *Astyanax* (Characiformes: Characidae) no sul do Brasil

Resumo: A espécie de acantocéfalo *Quadrigyrus torquatus* Van Cleave, 1920, tem sido encontrada em diferentes hospedeiros na América do Sul, contudo os estudos recentes não focam no estudo dos caracteres morfológicos. Diferentes espécies de *Astyanax* Baird & Girard, 1854 foram coletadas com redes do tipo picaré entre janeiro e outubro de 2017, na Ilha da Pintada, Lago Guaíba, Cidade de Porto Alegre (30º17'11"S e 51º18'01"W), Estado do Rio Grande do Sul, Brasil. Os acantocéfalos encontrados encistados foram processados de acordo com as técnicas para o grupo. Os espécimes de *Q. torquatus* foram identificados principalmente pela morfologia dos ganchos da probóscide, espinhos do tronco e, pelas medidas realizadas através de microscopia de luz. Observações suplementares na morfologia de *Q. torquatus* foram realizadas pela primeira vez, considerando a morfologia e o número de ganchos e espinhos. A amplitude das infecções foi 1 (*A.* aff. *fasciatus*) e 1–3 (*A. lacustris*) helmintos. Esta diferença pode estar associada com o número de hospedeiros examinados, com os hábitos alimentares dos hospedeiros, ou relacionada com aspectos no ciclo de vida do parasito. Este estudo é o primeiro registro de *Q. torquatus* em *A.* aff. *fasciatus* e *A. lacustris* do Lago Guaíba, estendendo a distribuição do parasito para o sul do Brasil, contribuindo com o conhecimento dos acantocéfalos parasitos de peixes de água doce na América do Sul.
Palavras-chave: *Acantocéfalo, helmintos, endoparasito, taxonomia, região Neotropical.*

Introduction

According to the most recent proposal of classification of acanthocephalans, the family Quadrigyridae Van Cleave, 1920 encompasses two subfamilies: Pallisentinae Van Cleave, 1928 and Quadrigyrinae Van Cleave, 1920. The genera *Acanthodelta* Diaz-Ungria & Garcia-Rodrigo, 1958, *Machadosenstis* Noronha, 1992 and *Quadrigyrus* Van Cleave, 1920 are currently assigned to the subfamily Quadrigyrinae (Amin 2013).

Van Cleave (1920) when proposed the genus *Quadrigyrus*, described *Quadrigyrus torquatus* Van Cleave, 1920 as type-species. At that time, the species description was based on specimens of *Q. torquatus* collected from *Hoplias malabaricus* (Bloch, 1794) in the Lake Valencia, city of Maracay (type-locality) and in Isla de Burro, both in Venezuela. This author found the parasite in other hosts: *Synbranchus marmoratus* Bloch, 1795, *Crenicichla geayi* Pellegrin, 1903, *Gephyrocharax valencia* Eigenmann, 1920 and *Astyanax bimaculatus* (Linnaeus, 1758). Until now, nine species of *Quadrigyrus* are considered valid (Amin 2013). From these, four species (*Quadrigyrus brasiliensis* Machado Filho, 1941, *Quadrigyrus machadoi* Fabio, 1983, *Quadrigyrus nickoli* Schmidt & Hugghins, 1973 and *Q. torquatus*) were reported from South America (Thatcher 2006, Santos et al. 2008, Fujimoto et al. 2013).

A total of 20 species of *Astyanax* Baird & Girard, 1854 have been reported from Rio Grande do Sul State, southern Brazil. These species are found in the Uruguay river drainage basin, Patos Lagoon system, and in Tramandaí river system (Lucena et al. 2017). In Lake Guaíba the following species of *Astyanax* have been considered abundant: *Astyanax eigenmanniorum* (Cope, 1894), *Astyanax* aff. *fasciatus* (Cuvier, 1819), *Astyanax henseli* Melo & Buckup, 2006 and *Astyanax lacustris* (Lütken, 1875). Until now, two species of digenetic trematodes, two species of monogeneans and one species of nematode were recorded from species of *Astyanax* in the Lake Guaíba (Fortes & Hoffmann 1999, Gallas et al. 2014, 2015, 2016), but no acanthocephalans were observed parasitizing species of this genus.

In Brazil, there are reports of *Q. torquatus* from different hosts collected in States of Pará, Mato Grosso, Rio de Janeiro and Paraná (Machado Filho 1941, Carvalho et al. 2003, Guidelli et al. 2006, Santos et al. 2008, Fujimoto et al. 2013), but no records have been made for Rio Grande do Sul State. The present study reports for the first time the acanthocephalan *Q. torquatus* in two species of *Astyanax* from Lake Guaíba, southern Brazil.

Material and Methods

Specimens of *A. eigenmanniorum* (n = 11), *A.* aff. *fasciatus* (n = 44), *A. henseli* (n = 5) and *A. lacustris* (n = 25) were collected with seine nets between January 2017 and October 2017 in Pintada Island, Lake Guaíba, Porto Alegre city (30º17'11''S and 51º18'01"W), Rio Grande do Sul State, Brazil. Individual fishes were stored in separate plastic bags and kept under refrigeration until necropsy. Fishes were necropsied, and each organ was placed individually in Petri dishes. Acanthocephalans found in cysts were released and placed in distilled water for 48 hours under cold temperature. This procedure led to the evagination of the proboscis. Helminths were fixed in A.F.A. for 48 hours and then, stored in 70º GL ethanol (Amato & Amato 2010). Acanthocephalans were stained with Delafield's hematoxylin, clarified and later mounted on slides using Canada balsam.

Measurements were made using an ocular micrometer in a light microscope and, are shown in micrometers (µm), unless otherwise indicated, and represent the range followed between parenthesis by the mean, the standard deviation, and the sample size. Hooks and spines were measured considering the blade and root length (Brázová et al. 2014), and the base length of the hooks. Line drawings and photomicrographs were made using a Zeiss Axiostar or a Olympus BX50 microscope, scanned and prepared using CorelDraw X4® and Adobe's Photoshop® CS2. Ecological parameters follow Bush et al. (1997). Voucher specimens of the helminths were deposited in the 'Coleção Helmintológica do Instituto Oswaldo Cruz' (CHIOC), Rio de Janeiro, Rio de Janeiro State, Brazil. Hosts were identified following Bertaco & Lucena (2010) and Lucena et al. (2013). The study was approved by the Institutional Committee.

Results

Quadrigyrus Van Cleave, 1920

Quadrigyrus torquatus Van Cleave, 1920 (cystacants)

Figures 1–3

Description. Quadrigyridae, Quadrigyrinae. Based on seven specimens (five males and two females). Whitish cystacants in life, cyst free in the small intestine. Proboscis armed with 10 longitudinal rows of two hooks each, forming four transversal circles of hooks (figures 1a, 1b, 2a and 3a). The apical hooks present a small manubrium, slightly visible (figures 1c, 2b and 3a); all of the hooks present a well developed root. Proboscis receptacle of one muscular layer, with cerebral ganglion next to the base (figure 1b). Trunk with four transversal circles of spines in the anterior region (figures 1a, 1b, 1d, 2a, 2c and 3b). Lemnisci claviform, with large nuclei (figure 1b). Nuclei in the tegument of two types: anterior middle dorsal and medium ventral and, the others branched and lateral.

Males (n = 5). Body 3.62 mm long, 0.6–0.65 mm (0.62 ± 0.02 mm) wide at lemnisci level and, 0.35–0.47 mm (0.43 ± 0.05 mm) wide at testes level. Proboscis 160 long and 150 wide. Hooks of first circle 77–87 (83 ± 4; n = 6) long, base 15–20 (18 ± 2; n = 6) long; root 50–57 (54 ± 2; n = 6) long. Hooks of second circle 72–82 (77 ± 4; n = 6) long, base 12–20 (16 ± 2; n = 6) long; root 45–47 (46; ± 1; n = 6) long. Hooks of third circle 47–55 (52 ± 3; n = 6) long, base 7–12 (10 ± 1; n = 6) long; root 20–32 (25 ± 4; n = 6) long. Hooks of fourth circle 37–45 (41 ± 3; n = 6) long, base 5–8 (7 ± 1; n = 6) long; root 12–20 (16 ± 2; n = 6) long. Trunk with four transversal circles of spines, with 17 to 21 spines in each circle. Spines of the first circle 17–20 (18 ± 1; n = 4) long, root 15–17 (16 ± 1; n = 4) long. Spines of the second circle 15–17 (16 ± 1; n = 5) long, root 12–15 (13 ± 1; n = 5) long. Spines of the third circle 15–17 (16 ± 1; n = 5) long, root 10–15 (13 ± 2; n = 5) long. Spines of the fourth circle 12–17 (15 ± 2; n = 5) long, root 12–15 (14 ± 1; n = 5) long. Proboscis receptacle 300 long, 80–150 (115 ± 35; n = 2) long. Lemnisci 520–700 (601 ± 61; n = 5) long, 80–150 (120 ± 27; n = 5) wide. Oval testes, *in tandem*, 180–280 (226 ± 33; n = 10) long, 80–120 (98 ± 13; n = 6) wide (figure 2d). Cement glands not visualized and, Saefftigen's pouch in development. Copulatory bursa 90–130 (108 ± 13; n = 5) long, 70–80 (78 ± 4; n = 5) wide (figure 2e).

Females (n = 2). Body 5.9 mm long, 0.62–0.75 mm (0.69 ± 0.06 mm; n = 2) wide at level of lemnisci and, 0.37–0.47 mm (0.42 ± 0.05 mm; n = 2) wide at middle body. Proboscis 190 long, 180 wide.

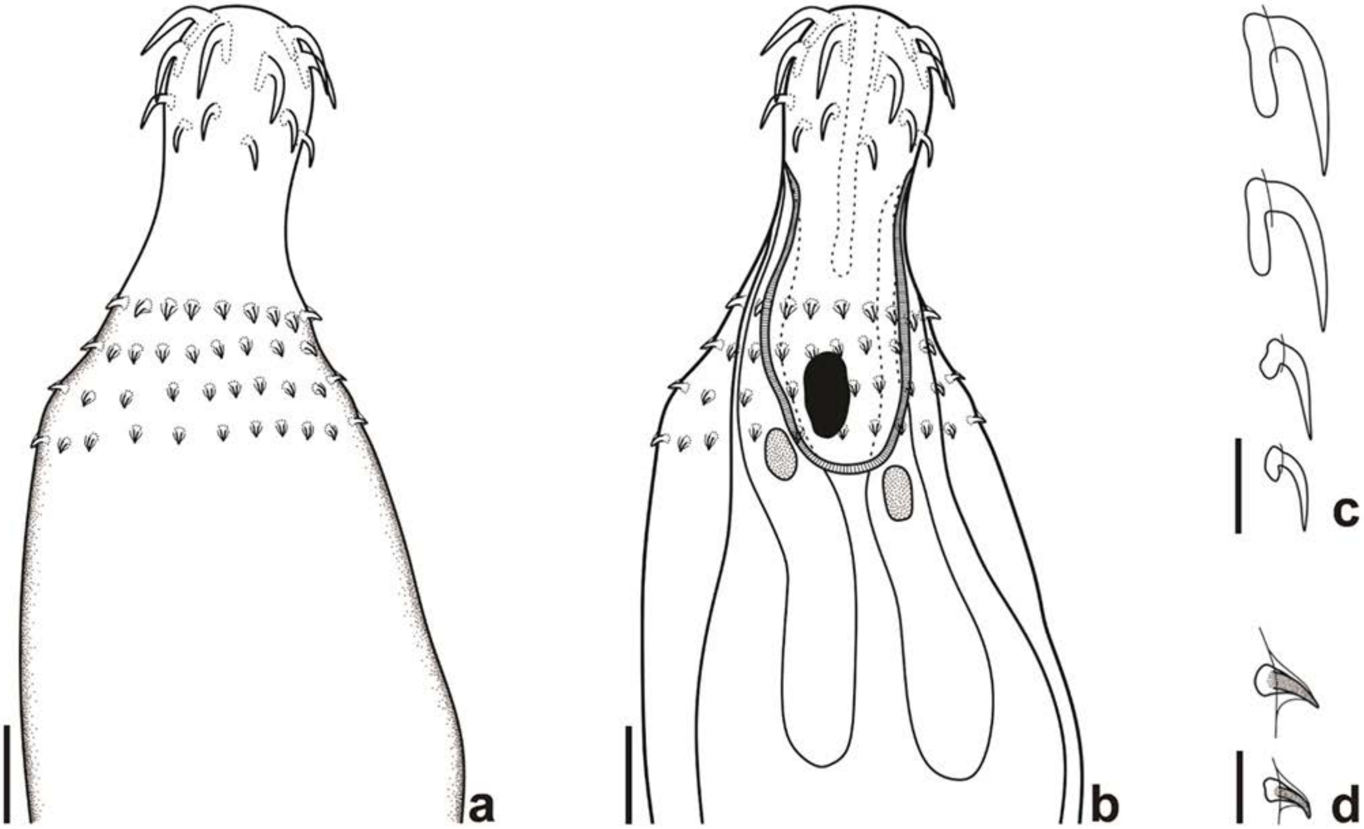

FIGURE 1. *Quadrigyrus torquatus* Van Cleave, 1920. a. External view of the anterior end showing the hooks in the proboscis and the spines in the trunk. Scale bar = 100 µm. b. Internal view of the anterior end. Scale bar = 100 µm. c. Hooks. Scale bar = 50 µm. d. Spines of the trunk. Scale bar = 20 µm.

Hooks of first circle 80–90 (85 ± 4; n = 3) long, base 17–20 (18 ± 1; n = 3) long; root 55–60 (57 ± 2; n = 3) long. Hooks of second circle 80–85 (82 ± 2; n = 4) long, base 17–20 (18 ± 1; n = 4) long; root 52–57 (56 ± 2; n = 3) long. Hooks of third circle 55 (n = 4) long, base 10 (n = 4) long; root 17–25 (22 ± 3; n = 4) long. Hooks of fourth circle 40–47 (42 ± 3; n = 4) long, base 7–10 (9 ± 1; n = 4) long; root 15–17 (16 ± 1; n = 4) long. Trunk with four transversal circles of spines, with 19 to 20 spines in each circle. Spines of the first circle 20–22 (21 ± 1; n = 2) long, root 12–15 (14 ± 1; n = 2) long. Spines of the second circle 17 (n = 2) long, root 15 (n = 2) long. Spines of third circle 15 (n = 2) long, root 15–17 (16 ± 1; n = 2) long. Spines of fourth circle 15 (n = 2) long, root 12–15 (14 ± 1; n = 2) long. Proboscis receptacle 330 long, 180–210 (195 ± 15; n = 2) wide. Lemnisci 470–680 (575 ± 105; n = 2) long, 80–110 (95 ± 15; n = 4) wide. Ovary not visualized. Uterine bell 70–80 (75 ± 5; n = 2) long, 40–50 (45 ± 5; n = 2) wide (fig 10). Uterus 230–310 (270 ± 40; n = 2) long, 30–40 (35 ± 5; n = 2) wide. Vagina 140–170 (155 ± 15; n = 2) long, with two sphincters (figure 2f), the anterior 50 (n = 2) long, 57–80 (69 ± 11; n = 2) wide; and the posterior 20–25 (22 ± 2; n = 2) long, 25–37 (31 ± 6; n = 2) wide. Genital pore 50–120 (85 ± 35; n = 2) from posterior end.

1. *Taxonomic summary*

Hosts: *Astyanax* aff. *fasciatus* (Cuvier, 1819) and *Astyanax lacustris* (Lütken, 1875).

Locality: Pintada Island, Lake Guaíba, Porto Alegre city (30º17’11’’S and 51º18’01”W), Rio Grande do Sul state, Brazil.

Site of infection: small intestine.

Prevalence: 6.81% (*A*. aff. *fasciatus*) and 12% (*A. lacustris*).

Mean intensity of infections: 1 helminth/host (*A*. aff. *fasciatus*) and 1.66 helminths/host (*A. lacustris*).

Mean abundance of infections: 0.06 helminth/host (*A*. aff. *fasciatus*) and 0.2 helminth/host (*A. lacustris*).

Amplitude of intensity of infections: 1 (*A*. aff. *fasciatus*) and 1–3 (*A. lacustris*).

Voucher specimens of the helminths deposited: CHIOC 40060-male, CHIOC 40061- female.

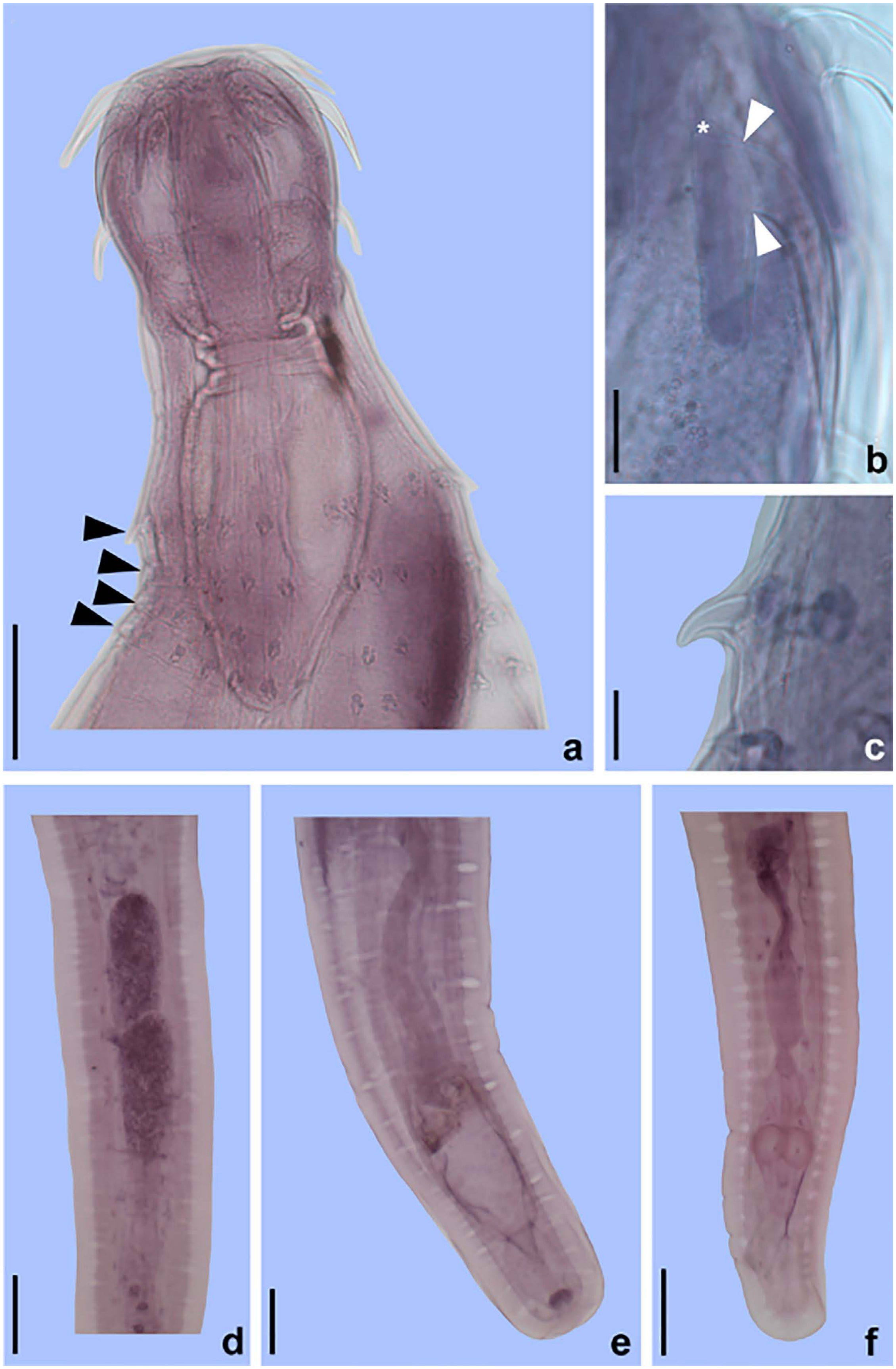

FIGURE 2. *Quadrigyrus torquatus* Van Cleave, 1920. a. Anterior end showing the four circles of spines (arrow heads). Scale bar = 100 µm. b. Detail of the hook showing the limit of the blade and the small manubrium (asterisk). Scale bar = 20 µm. c. Detail of the spine of the trunk. Scale bar = 15 µm. d. Middle region of the body showing the testes. Scale bar = 150 µm. e. Posterior end of male. Scale bar = 150 µm. f. Posterior end of female. Scale bar = 100 µm.

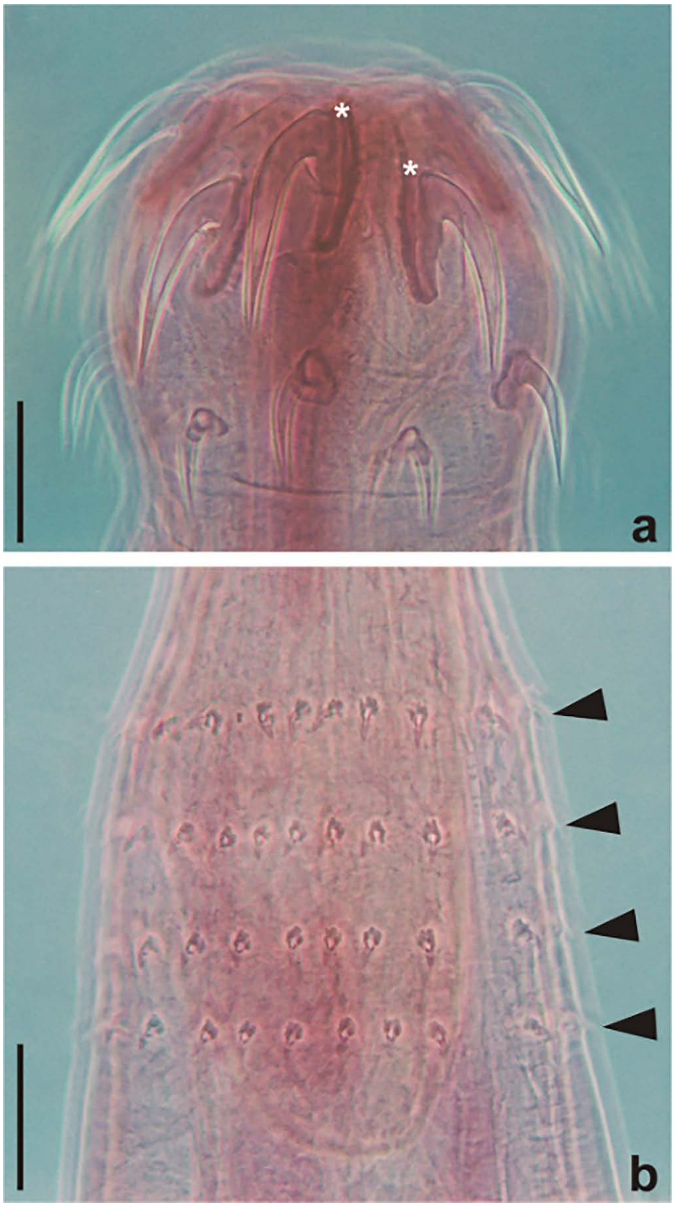

FIGURE 3. *Quadrigyrus torquatus* Van Cleave, 1920, observed with phase contrast. a. Anterior end showing the proboscis with a hook showing the small manubria (asterisks). Scale bar = 50 µm. b. Detail of the trunk showing the four circles of spines (arrow heads). Scale bar = 100 µm.

Discussion

The four species of *Quadrigyrus* reported from South America (*Q. brasiliensis*, *Q. machadoi*, *Q. nickoli*, and *Q. torquatus*) (Thatcher 2006, Santos et al. 2008, Fujimoto et al. 2013) could be differentiate by the number of rows and the quantity of spines in the trunk: *Q. brasiliensis* presents three circles with 12 spines each; *Q. machadoi* has three to six circles with spines (the number of spines by each circle is unknown); *Q. nickoli* presents four circles with 23 to 29 spines each (Schmidt & Hugghins 1973, Fabio 1983, Thatcher 1991). However, the descriptions of the quantity of spines in the trunk of *Q. torquatus* vary in the literature. For example, Van Cleave (1920) reported specimens with four circles of spines (the number of spines was not informed in the text, but from the drawings, about 10 spines could be observed in one view); Schmidt & Hugghins (1973) found specimens with three to four circles of 10 to 18 spines each, an description also found in Thatcher (1991, 2006), which possibly compiled data from Schmidt & Hugghins (1973).

The specimens found in the present study presented four circles of spines; however the quantity of spines by circle was higher (17–21) than the amount (10–18) reported by Schmidt & Hugghins (1973). According to Van Cleave (1920), the quantification of spines in mature specimens of *Q. torquatus* is more difficult than in the young specimens, and this could be the reason for the low number of spines observed by Schmidt & Hugghins (1973). Although the number of spines in the trunk of *Q. nickoli* (23–29) is similar to the maximum number of the spines (21) in the specimens found in the present study, the size of the hooks and the amount of spines led the morphological identification of the cystacants as *Q. torquatus*.

The prevalence of *Q. torquatus* seems to be lower in the paratenic hosts *A.* aff. *fasciatus* (6.81%; n = 44) and *A. lacustris* (12%; n = 25) found in the present study, and *Leporinus lacustris* Campos, 1945 (1.33%; n = 150) (Guidelli et al. 2006), in relation to the definitive hosts *Acestrorhynchus lacustris* (Lütken, 1875) (37.2%; n = 51) (Carvalho et al. 2003). The difference in the prevalence could be related to several factors, such as host life habits and feeding (freshwater fish hosts with an omnivorous or piscivorous diet are frequently parasitized by acanthocephalans), and characteristics related to the parasite life cycle (presence of the intermediate hosts in the environments, and the fact that the larvae must be ingested by a suitable host) (Nickol 1985, Kennedy 2006). The number of hosts examined in each study could also influence the prevalence, since this parameter is obtained considering the number of hosts parasitized and non-parasitized (Bush et al. 1997). More studies are necessary to confirm the hypothesis of the high-low prevalence of *Q. torquatus* in different types of hosts.

In the life cycle of the species of *Quadrigyrus*, carnivore fish are considered to be the definitive hosts, and two species of *Astyanax* (*A. bimaculatus* and *Astyanax altiparanae* Garutti & Britski, 2000) have been reported as paratenic hosts (Van Cleave 1920, Carvalho et al. 2003, Rosim et al. 2005, Lizama et al. 2008, Fujimoto et al. 2013). The presence of *Q. torquatus* in *A.* aff. *fasciatus* and *A. lacustris* in this study reflects the position of these fish in the food web: the characids are paratenic hosts harboring the cystacants of *Q. torquatus* which will reach the adult stage after being eat by a carnivore fish (definitive host).

The richness of the species of acanthocephalans parasitizing *Astyanax* spp. in South America is extremely low, with reports in *A. bimaculatus* (Van Cleave 1920, Fujimoto et al. 2013) and *A. altiparanae* (Lizama et al. 2008). The following species were reported as definitive or paratenic hosts of *Q. torquatus* in Brazil: *A. bimaculatus*, *Ac. lacustris*, *H. malabaricus*, *L. lacustris* e *Moenkhausia sanctaefilomenae* (Steindachner, 1907) (Machado Filho 1941, Carvalho et al. 2003, Guidelli et al. 2006, Santos et al. 2008, Fujimoto et al. 2013). This is the first report of *Q. torquatus* cystacants in *A.* aff. *fasciatus* and *A. lacustris* from Lake Guaíba, extending the distribution to the southernmost state of Brazil. The present study contributes to the knowledge of the helminth fauna of species of *Astyanax* in freshwater ecosystems, the most rich and threatened environments on Earth (Geist 2011).

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Author Contributions

Moisés Gallas: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Laura R. P. Utz: Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

The study is approved by the Institutional Committee.

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Erratum

Erratum: Ichthyofauna marine of the Island of Santa Catarina, Southern Brazil: checklist with comments on the species

In the article "Ichthyofauna marine of the Island of Santa Catarina, Southern Brazil: checklist with comments on the species" with the DOI code number http://dx.doi.org/10.1590/1676-0611-BN-2018-0684, published at Biota Neotropica 19(3): e20180684, the title should be

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Instead of:

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Short Communication

Occurrence of tayras (*Eira barbara* Linnaeus, 1758) with anomalous coloration in Cerrado remnants in the state of São Paulo, Brazil

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Abstract: Coloration anomalies are mainly genetically-based disorders in which body pigmentation is either reduced (hypopigmentation) or produced in excess (melanism), in parts or the totality of the body. Cases of hypopigmentation have been documented in many neotropical mammals, including the tayra (*Eira barbara* Linnaeus, 1758). We expand the account of anomalous coloration occurrence presenting new registers of hypopigmented tayras in Brazil. Data was collected during a mammal survey carried out in three agricultural landscapes within the Cerrado domain in the northeast of the state of São Paulo. We obtained two kinds of records of hypopigmented tayras, one from direct sighting and the other from a camera-trap. We discuss the likely implications of this conspicuous coloration to tayras and highlight some possibilities of study.

Keywords: *Anthropogenic matrix, hypopigmentation, leucism, mustelid, savannah, sugarcane.*

Ocorrência de iraras (*Eira barbara* Linnaeus, 1758) com coloração anômala em remanescentes de Cerrado no estado de São Paulo, Brasil

Resumo: Colorações anômalas são desordens geralmente de origem genética, em que a pigmentação do corpo é reduzida (hipopigmentação) ou excessiva (melanismo), em partes ou totalmente. Casos de hipopigmentação já foram documentados em muitos mamíferos neotropicais, incluindo a irara (*Eira barbara* Linnaeus, 1758). Nós expandimos os relatos de ocorrência de colorações anômalas apresentando novos registros de iraras hipopigmentadas no Brasil. Dados foram coletados durante um levantamento de mamíferos em três paisagens agrícolas no domínio do Cerrado no nordeste do estado de São Paulo. Obtivemos dois tipos de registros de iraras hipopigmentadas, sendo um por avistamento e outro por armadilhas fotográficas. Nós discutimos possíveis implicações ecológicas dessa coloração em iraras e sugerimos novas possibilidades de estudos.

Palavras-chave: *Cana-de-açúcar, hipopigmentação, leucismo, mustelídeo, matriz antrópica, savana.*

Introduction

Animal coloration is widely involved in life processes such as concealment, communication, physiological regulation and sexual selection (Caro 2005). Presence and distribution of pigmentation in animals' skin, hair and eyes define different colour phenotypes (Fertl & Rosel, 2002, Hofreiter & Schöneberg 2010). The physical environment is an important selective force driving coloration patterns in mammals, resulting in a gradual variation in colour across populations (Ortolani 1999). Moreover, variation is also attributed to colour anomalies that occur when integumentary pigments are present in excess or deficient in parts or in totality of the body, being described as melanism, piebaldism, hypomelanism, leucism and albinism (Prota 1980, Fertl & Rosel 2002, Lucati & Lopez-Baucells 2016).

Specifically, leucism is a condition in which body pigmentation is fully absent, but differently from albinism, the eyes of leucistic animals retain normal coloration (Lucati & Lopez-Baucells 2016). The subject is rather controversial, but most authors sustain that leucism is characterised by total *or* partial absence of pigmentation in the whole body except for the eyes and body extremities, which remain darkly pigmented (Fertl and Rosel, 2002; Miller, 2005; Acevedo and Aguayo, 2008). Leucism is commonly confounded with other hypopigmentary disorders, such as piebaldism and hypomelanism (Lucati & Lopez-Baucells 2016). Piebaldism is a type of localised hypopigmentation, due to an absence of melanocytes in the affected skin and hair follicles or feathers. Piebald animals have normally coloured eye and a patchy distribution of spots on the body where both fur and skin are totally white (Lucati & Lopez-Baucells 2016). Hypomelanism is another type of chromatic disorder that turns individuals yellowish due to an insufficiently pigmented skin (Lucati & Lopez-Baucells 2016). In general, anomalous coloration are attributed to genetic hereditary causes (Bensch et al. 2000), involving the lack of production of tyrosinase, the enzyme involved in melanin biosynthesis (Sanchez-Ferrer et al. 1995), or a deficiency in the melanin transfer process, despite normal pigment production (Lucati & Lopez-Baucells 2016). Despite strong selection pressures against hypopigmented animals, these anomalous colours have been recorded in many mammalian species (Fertl & Rosel 2002, Abreu et al. 2013).

Coloration anomalies have been identified in terrestrial carnivore species such as the tayra (*Eira barbara* Linnaeus, 1758; Sobroza et al. 2016), the white-nosed coati (*Nasua narica* Linnaeus, 1766; Silva-Caballero et al. 2014) and the neotropical otter (*Lontra longicaudis* Olfers, 1818; Arriaga-Flores et al. 2016). The tayra is one of the most common medium sized carnivores in Neotropical forests (Emmons & Feer 1997), being broadly distributed from central Mexico to northern Argentina (Presley 2000). Throughout its distribution, tayras with anomalous coloration have been identified in Guyana (Presley 2000), Bolivia (Tarifa et al. 2001) and Brazil (Trolle 2003, Reis et al. 2005, Tortato & Althoff 2007, Sobroza et al. 2016, Aximoff & Rosa 2016, Talamoni et al. 2017). The subspecies that occurs in most of Brazil, *Eira barbara barbara*, presents a dark brown body coat with a grey head and a whitish spot at the base of the neck extending to the chest (Presley 2000). To date, there are six reports evidencing anomalous coloration in tayras around the country. Two occurrences were described from Central Amazon, in the sub-basin of the Rio Negro (Trolle 2003) and from the "Cabo Frio" site of the Biological Dynamics of Forest Fragments Project (BDFFP) (Sobroza et al. 2016). In the south part of Brazil, whitish tayras were spotted on a farm in the state of Paraná, where native pastures are predominant (Reis et al. 2005), and in the state of Santa Catarina (Tortato & Althoff 2007), within a transition area between mixed and dense Ombrophylous Forests. More recently, in the southeast region of Brazil, one record of an albino tayra was made in the Atlantic Forest of the Itatiaia National Park, Rio de Janeiro state (Aximoff & Rosa 2016), and some records of leucistic tayras were made at the Private Reserve of Natural Heritage Santuário do Caraça, in Minas Gerais state, a transition zone between Cerrado (i.e. brazilian savanna) and Atlantic Forest (Talamoni et al. 2017). In this report, we present new records of anomalous coloration in tayras for the southern limits of the Brazilian Cerrado and the first record for the state of São Paulo.

Materials and Methods

The data presented here was collected during a project evaluating the effects of environmental variables and anthropogenic disturbance on occupancy of mammal species in southeast Brazil (Paolino et al. 2016, Rodrigues et al. 2017). The study was carried out in three agricultural landscapes within the Cerrado domain in São Paulo state (Figure 1). The region is also a transition zone between Cerrado and Atlantic Forest, characterized often by remnants of Cerrado physiognomies, mostly "Cerradão" (sclerophyllous woodland, Toppa 2004). The remnants are surrounded by a heterogeneous matrix made up of *Eucalyptus* and sugarcane plantations, other agricultural crops and urban areas (Rodrigues et al. 2017). Each of the three study landscapes differed in land cover type composition. Landscape A included two protected areas called Jataí Ecological Station (JES) and Luiz Antônio Experimental Station (LAES), adjacent to each other; landscape B included Legal Reserves and Areas of Permanent Protection (Soares-Filho et al. 2014) of a private area owned by International Paper called Cara Preta Farm (CPF); and landscape C included a protected area called Cajuru State Forest (CSF), Areas of Permanent Protection and a Legal Reserve of another private farm from International Paper called Dois Córregos Farm (DCF). We also collected data (see below) in a buffer zone up to 2.6 km from the perimeters of the protected areas, Legal Reserves and Areas of Permanent Protection mentioned above (Figure 1).

A regular grid of 200 ha cells was overlaid on the study landscapes and a single camera-trap (Reconyx®, model HC 500) was placed in the centre of each cell. From April to September 2013-2014, 208 sites were sampled with all camera-traps spaced approximately 1.4 km apart on each landscape. Camera-traps were systematically placed inside JES-LAES (n = 52), CPF (n = 25) and CSF-DCF (n = 24) and a similar number was randomly placed in the buffer zone around each one. We programmed the cameras to monitor 24 hour/day and each of them operated continuously for about 30 days, totalling a sampling effort of 6,380.92 camera-trap days. We fixed the camera-traps on tree trunks 40-60 cm above the ground. Additionally, we actively searched for signs (footprints, scats, etc.) or sightings in the surroundings of each camera-trap during their installation and removal.

Results and Discussion

Over the whole study period, we detected tayras in 17 out of 208 sampling sites (8.17%). We obtained two records of yellow-whitish tayras, one from an animal directly sighted by us and the other from

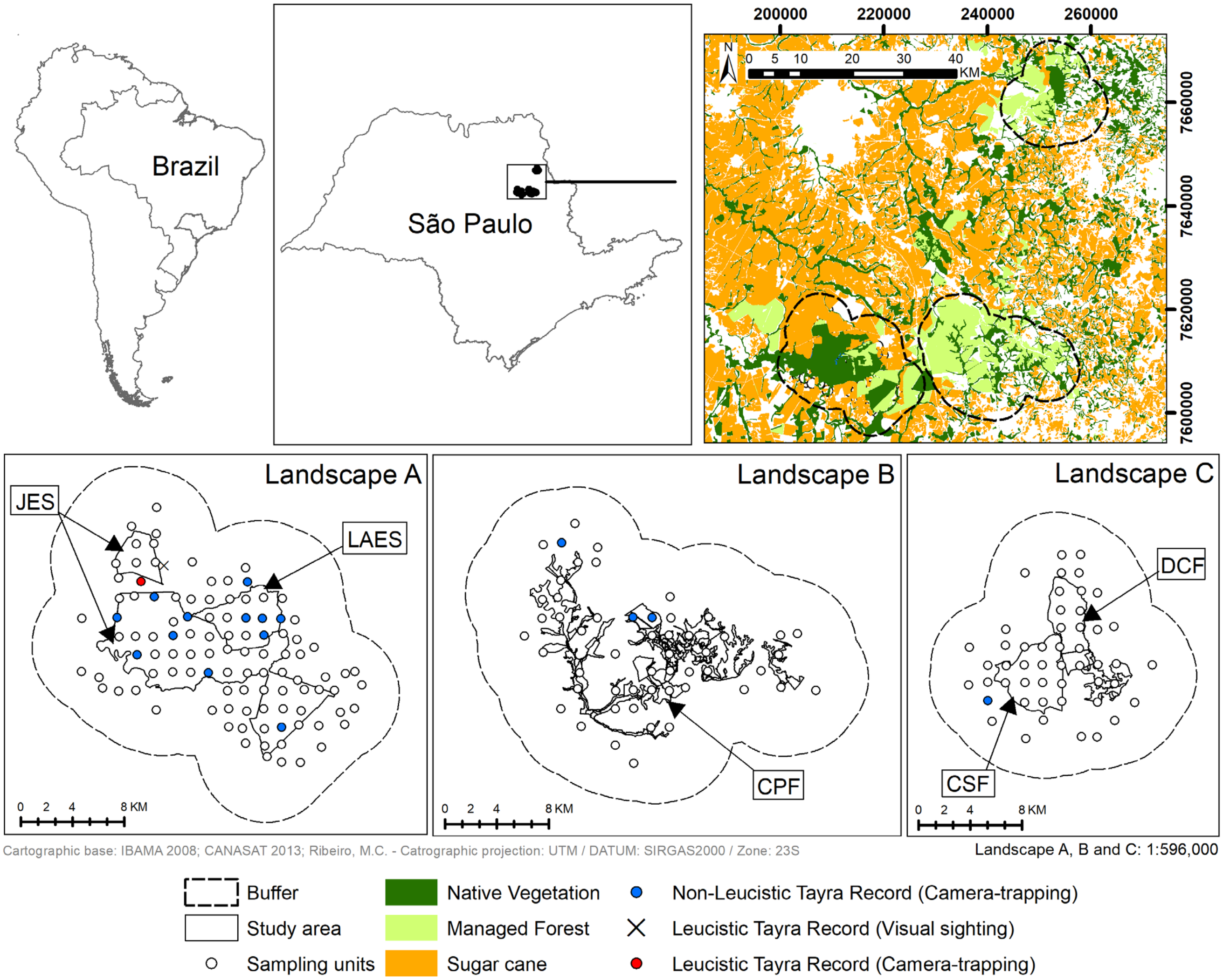

Figure 1. Details of the study areas. Landscape A: Jataí Ecological Station (JES) and Luis Antônio Experimental Station (LAES); Landscape B: Cara Preta Farm (CPF); Landscape C: Cajuru State Forest (CSF) and Dois Córregos Farm (DCF). Each sampling unit is represented by uncoloured dots; blue dots represent tayra registers by camera trap and the red dot shows the location where leucistic tayras were detected by camera trap; the "x" represents the location where the leucistic tayra was recorded by visual sighting.

a single camera-trap (n= 15 photographs). The sighted individual was crossing a paved road that separates a sugarcane field from native vegetation (21°32'27.5" S, 47°48'09.3" W) at 15:30 on August 2013. The record from the camera-trap shows two tayras moving along an unpaved road at 7:58 on May 2013 (Figure 2). This unpaved road is also located between native forest and a sugarcane field (21°33'06.5" S, 47°49'12.0" W).

The two records are 2167 m apart and both are in the buffer zone of Jataí Ecological Station (landscape A), the largest Cerrado remnant of São Paulo state. The 200 ha buffer around the camera station where tayras with anomalous coloration were photographed is predominantly covered by closed native vegetation ("Cerradão"). It was not possible to discriminate the sex of the individuals with certainty, but the difference in body size between them suggests it could be either a female with a juvenile offspring or an adult couple, since male tayras are in general 30% larger than females (Kaufmann & Kaufmann 1965).

According to the definitions of anomalous coloration in mammals given by some authors (e.g. Fertl and Rosel, 2002; Miller, 2005; Acevedo and Aguayo, 2008) and considering the characteristics shown by the reported individuals (apparent lack of colour throughout the body and maintenance of dark pigmentation in the eyes and in the body extremities such as the nose), our records may represent leucistic tayras. However, considering the most recent definition of leucism, given by Lucati & Lopez-Baucells (2016), the entire body of a leucistic animal would have a white or whitish colour. Being mindful of the terminology misuse of anomalous coloration in the scientific literature, we refrain to designate our records as cases of leucism because we cannot precisely differentiate leucism from another hypopigmentary disorder like hypomelanism, given the nature of our data. For example, we are not sure that the tayras that we recorded present darker extremities as these might have resulted not from pelage coloration but from dirt or from shadows in the camera-trap photos. Nevertheless, tayras with normal coloration have browner body extremities than the observable in these two individuals, as shown in Figure 3. Anomalous colour phenotypes have been already identified in tayras across different landscapes and areas of occurrence, mainly in Brazil (Talamoni et al. 2017). Although hypopigmentation in

Figure 2. A, B and C. Pair of leucistic greyheaded tayras registered in landscape A (buffer zone of Jataí Ecological Station), in the state of São Paulo, Brazil; D. Highlight in one of the two individuals registered by camera trap.

Figure 3. Tayra presenting normal coloration, registered by camera-trap.

tayras have been detected in the Amazon, the Atlantic Forest and in a transitional area between Cerrado and Ombrophyllous Forests (Presley 2000, Trolle 2003, Reis et al. 2005, Tortato & Althoff 2007, Sobroza et al. 2016, Aximoff & Rosa 2016), our records are the first ones for the Cerrado region in the state of São Paulo, Brazil.

The occurrence of anomalous coloration in tayras recorded twice at landscape A (JES/LAES and surroundings) represent 13.3% of the records we obtained from this species in this landscape. This proportion of anomalous coloration over the low number of tayras recorded during the two-year study could be indicative of a small and isolated population that resulted from Cerrado deforestation and fragmentation (Seoane et al. 2010). The Jataí Ecological Station is an example of such fragment, being a Cerrado remnant (mostly “Cerradão”) surrounded by an anthropogenic matrix where sugarcane plantations predominate (Toppa 2004, Rodrigues et al. 2017). Nevertheless, apart from genetic assessment, we need further data on local population size and on dispersal potential of tayras through anthropogenic matrices to back this.

Studies of animal coat coloration can provide useful information on their ecology, however, reports of hypopigmentation in tayras lack the ecological implications of this phenotype (Talamoni et al. 2017). For instance, the possibility that tayras with partial or total lack of pigmentation are more susceptible to predation, due to its outstanding coloration at different environments, has never been tested nor assessed. Yet, this condition might turn hypopigmented tayras more vulnerable to larger, visually oriented carnivores such as cougars (*Puma concolor* Linnaeus, 1771) and ocelots (*Leopardus pardalis* Linnaeus, 1758), both of which are known to occur in our study area (Paolino et al. 2016). It is indeed possible to design and set up camera-trap appropriately in order to overcome the key limitation of individual identification, a necessary condition to estimate survival probabilities of classic population models. Villafañe-Trujillo & López-González (2018), for example, were able to identify individual tayras thorough pelage pattern of the head and chest. Estimating parameters such as survival rate could also help to investigate the possibility that individuals with anomalous coloration would have adaptive advantages (Talamoni et al. 2017). Conspicuous colour patterns in vertebrates are involved in a variety of intra and interspecific communicative interaction (Rowland 1979; Butcher & Rohwer 1989). Such abnormal coloration may aid in the recognition of species (Smith 1967), individuals (Miller & Eden 1975) and sexes (Noble 1936); may be used during territorial defence and aggression (Noble 1934; Tinbergen 1953); or to express courtship and mate preferences (Endler 1987, Houde & Endler 1990). According to Presley (2000), deficits in pigmentation production are more common in tayras than in other mustelids, therefore, reports on tayras' anomalous coloration across various landscapes present opportunities to investigate possible ecological adaptations in specific habitats. Given the nature of our records we cannot accurately infer about the population and ecological consequences of the anomalous colorations for the population of tayras in the Cerrado of São Paulo. However, we hope our records encourage further research on the basic causes of this phenomenon and its putative relationship with the environment.

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Author Contributions

Vitória M. Scrich: Contribution to manuscript preparation; Contribution to data analysis and interpretation.

Marcella C. Pônzio: Contribution to manuscript preparation; Contribution to data analysis and interpretation.

Nielson Pasqualotto: Contribution to data collection; Contribution to critical revision, adding intelectual content.

Thiago F. Rodrigues: Contribution to data collection; Contribution to critical revision, adding intelectual content.

Roberta M. Paolino: Contribution to data collection; Contribution to critical revision, adding intelectual content.

Adriano G. Chiarello: Substantial contribution in the concept and design of the study; Contribution to data analysis and interpretation; Contribution to critical revision, adding intelectual content.

Conflict of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Article

Diet and resource sharing by two Pimelodidae species in a Southeastern Brazilian reservoir

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Abstract: Fish can vary their diet and feeding dynamics according to biotic and abiotic factors. There is insufficient knowledge regarding these factors in reservoirs, which limits the management of these areas. The aim of this study was to determine the diet of two related and most collected fish species, verify the influence of biotic and abiotic factors on their diet, and also verify the existence of resource sharing by them in an upstream Brazilian reservoir. Fish abundance in the reservoir was calculated and data were provided by 176 specimens of *Iheringichthys labrosus* (Lütken, 1874) and 255 specimens of *Pimelodus maculatus* Lacépède, 1803 collected in Camargos reservoir, MG, Brazil. Stomach contents were analysed through the frequency of occurrence and volumetric methods. PERMANOVA analysis was done to evaluate the influence of biotic (Species and Size class) and abiotic factors (Season and Site) on the diets. The Alimentary Index (AI) and feeding overlap Index (Pianka) were also estimated. A NMDS analysis was conducted to visualize the food categories responsible for interspecific difference. The ingested items were grouped into 18 categories, of which 17 were found in both species. Feeding resources were significantly related to the biotic (Species: Pseudo F = 2.583, P = 0.001; Size Class: Pseudo F = 1.646, P = 0.001) and abiotic (Season: Pseudo F = 2.458, P = 0.006) factors. *I. labrosus* showed an invertivorous diet while *P. maculatus* an omnivorous diet and both species were not exclusively benthophagus as typically reported. Food overlap occurred intraspecifically and interspecifically (Pianka 0.61 to 0.97 and 0.61 to 0.66, respectively) and overlap also occurred in three of the four analysed seasons (Pianka 0.66 to 0.91). The diet overlap found between two of the most fished species and the low fish productivity may indicate the limitation of resources in this reservoir and should be considered for management of this area.

Keywords: *Feeding ecology, Iheringichthys labrosus, Pimelodus maculatus, Rio Grande Basin, upstream reservoir.*

Alimentação e compartilhamento de recursos por duas espécies de Pimelodidae em um reservatório do sudeste brasileiro

Resumo: Os peixes podem variar suas dietas e dinâmicas alimentares de acordo com fatores bióticos e abióticos. O conhecimento insuficiente desses fatores em reservatórios limita o manejo dessas áreas. O objetivo deste estudo foi determinar a dieta de duas espécies de peixes aparentados e mais coletados; verificar a influência de fatores bióticos e abióticos na dieta, e também verificar a existência da partilha de recursos entre essas espécies em um reservatório brasileiro de cabeceira. A abundância de peixes foi calculada e dados foram fornecidos por 176 espécimes de *Iheringichthys labrosus* (Lütken, 1874) e 255 espécimes de *Pimelodus maculatus* Lacépède, 1803 coletados no reservatório de Camargos, MG, Brasil. O conteúdo estomacal foi analisado pelos métodos de frequência de ocorrência e volumétrico. A análise de PERMANOVA foi realizada para avaliar a influência de fatores bióticos (Espécies e Classe de tamanho) e abióticos (Estação e Local) nas dietas. O Índice Alimentar (IA) e o Índice de sobreposição alimentar (Pianka) também foram estimados. Uma análise de NMDS foi conduzida para visualizar as categorias alimentares responsáveis pela diferença interespecífica. Os itens ingeridos foram agrupados em 18 categorias, das quais 17 foram encontradas em ambas as espécies. Os recursos alimentares foram significativamente relacionados aos fatores bióticos (Espécies: Pseudo F = 2.583, P = 0.001; Classe de tamanho: Pseudo F = 1.646, P = 0.001) e abióticos (Estação: Pseudo F = 2.458, P = 0.006). *I. labrosus* mostrou uma dieta invertívora e *P. maculatus* uma dieta onívora e ambas as espécies não foram exclusivamente bentófagas como normalmente descritas. A sobreposição alimentar ocorreu intraespecífica e interespecífica (Pianka 0,61 a 0,97 e 0,61 a 0,66, respectivamente) e a sobreposição também ocorreu em três das quatro estações analisadas (Pianka 0,66 a 0,91). A sobreposição de dieta encontrada entre duas das espécies mais pescadas e a baixa produtividade pesqueira podem indicar a limitação de recursos nesse reservatório e devem ser consideradas para o manejo dessa área.

Palavras-chave: *Ecologia alimentar, Iheringichthys labrosus, Pimelodus maculatus, Bacia do Rio Grande, reservatório de cabeceira.*

Introduction

Fish ecology studies provide information on species biology and the dynamics of aquatic ecosystems. This in turn contributes to the development of measures for the conservation and management of fishery resources (Braga et al. 2012, Martins et al. 2017). Fish present different adaptations in their feeding habits, usually associated with spatial and seasonal changes in food availability (Wooton 1992). Thus, it is necessary to consider the influence of biotic and abiotic factors for a more accurate evaluation of their trophic ecology (Prejs & Colomine 1981, Vitule et al. 2008). The role of biotic and abiotic factors structuring freshwater fish communities was demonstrated by Magnan et al. (1994) and Jackson et al. (2001). Magnan et al. (1994) also reported the importance of works that simultaneously analyse the biotic, abiotic and spatial factors to determine the resource use by a species. In addition, resource partitioning regulates the biomass and the functioning of the Neotropical ichthyofauna (Abilhoa et al. 2016) and its study contributes to a better understanding of how species interact (Ross 1986).

The growing number of hydroelectric plants built in Brazil since the 1950s has made necessary to study the ichthyofauna in reservoirs. However, the dispersed and fragmented nature of these studies in time and space (Agostinho et al. 2007, Agostinho et al. 2016) compromises the correct management of reservoirs, especially with the growing demand for its multiple uses (Tundisi & Matsumura-Tundisi 2003).

The influence of biotic and abiotic factors on food resources was studied in some Brazilian reservoirs (Arcifa et al. 1992, Araújo et al. 2005, Pamplin et al. 2006). However, according to Araújo-Lima et al. (1995), trophic structure trends in reservoirs are associated to the characteristics of each reservoir. Food resource partitioning by related fish species has already been studied in Brazilian natural environments (Bonato & Fialho 2014, Abilhoa et al. 2016) and reservoirs (Arcifa et al. 1991, Albrecht et al. 2009). However, studies on the long-term consequences of impoundment are necessary to establish feeding ecology patterns in reservoirs (Luz-Agostinho et al. 2006, Hahn & Fugi 2007).

Both *Iheringichthys labrosus* (Lütken, 1874) and *Pimelodus maculatus* Lacépède, 1803 can be found among the native species of the Grande River. They belong to the order Siluriformes, family Pimelodidae, have common anatomical characteristics described by Lundberg & Littmann (2003) that are generally associated with benthic foraging habits (Nomura et al. 1972, Fugi et al. 1996, Abes et al. 2001, Fugi et al. 2001). *I. labrosus* has been classified as omnivorous, invertivorous or insectivorous species (Manetta et al. 2003, Luz-Agostinho et al. 2006, Fagundes et al. 2008, Ribeiro et al. 2014) and there is little information on its interaction with other species (Masdeu et al. 2011). *P. maculatus* is usually classified as an (opportunistic) omnivorous species (Basile-Martins et al. 1986, Silva et al. 2007) with tendency towards piscivory in rivers (Andrade & Braga 2005) or insectivory in reservoirs (Luz-Agostinho et al. 2006).

In the ichthyofauna surveys conducted between 1991 and 1995 in the Camargos reservoir, *I. labrosus* and *P. maculatus* were among the most collected species. In light of the numerous Brazilian reservoirs, it is important to understand the use of the resources, their variation and interaction among the most abundant fish species. Thus, the aim of the present study was: i) to determine the diet of *I. labrosus* and *P. maculatus*; ii) verify the influence of biotic and abiotic factors and iii) verify the existence of resource sharing between species, such *I. labrosus* and *P. maculatus*, in the Camargos reservoir, MG, Brazil.

Materials and Methods

1. *Study area*

The upper Paraná River basin, located in Southeastern Brazil, is the most affected basin by dams in the country and in the Grande River, one of its largest tributaries, there are 71 hydroelectric plants in operation (IPT 2008). The Camargos hydroelectric plant, which started operating in 1960, is the most upstream of the 12 plants located along the mainstream of the Rio Grande but licensing assessment for other upstream construction was underway (IPT 2008). Camargos is a storage reservoir (average water retention time of 58.8 days) that has a dendritic aspect with an area of 74 km^2 and volume maximum of 672 x 10^6 m^3 at an altitude of 913 m above sea level. This reservoir located in the upper section of the river has characteristics typical of many old, deep reservoirs (maximum depth of 32 m) as described by Agostinho et al. (2007), such as thermal and dissolved oxygen (DO) stratification (DO ranging from 6.2 mg/l at the bottom to 13.4 mg/l in the middle of the photic zone) (SISÁGUA, 2018). Additionally, the surrounding area is dominated by degraded native pasture (grass).

The region under the influence of the Camargos reservoir has transitional features between Cwb and Cwa according to Köppen-Geiger climate classification (Antunes 1986). These features are characterised by two distinct periods: one warmer and rainy (spring and summer:

October to March) and other less warm and dry (autumn and winter: from April to September) (Guimarães et al. 2010). The reservoir is at its highest level in autumn (April, May and July) due to the accumulation of summer rains. The lowest level occurs in spring (October, November and December) along with energy production prior to the next rainy season (Fig. 1). In this reservoir, three study sites were established after local investigation and fishing pre-test considering the different distances of the dam, the physical properties of the sites and the surrounding area (Table 1, Fig. 2).

2. *Data collection and laboratory procedures*

Twenty-four monthly samples were taken between February 1991 and January 1993. They occurred alternately in the three study sites and four seasons of the year, so that each site was sampled once per season in each year of study. In each sample, approximately 1200 m^2 of gill nets (20 m long and 1.6 to 1.8 m high), having sizes of 3, 4, 5, 6, 7, 8, 10, 12, 14 and 16 cm between opposing nodes, were set up in the late afternoon and removed the next morning. When it was possible, complementary trawling was also used to capture smaller specimens (5 m long, 1.5 m high and 5 mm mesh, used for 1 h). Thirty seven species were collected and the fish abundance in the reservoir was obtained by the catch per unit effort (CPUE) in number (CPUEn = number of fishes caught /100 m^2/12h) and biomass (CPUEb = weight of fishes caught in kg/100 m^2/12h). At the end of the 24 monthly samples, 1298 individuals of *I. labrosus* and 405 of *P. maculatus* were captured.

In the field, all collected fishes were kept in ice. They were subsequently labelled, identified, measured and dissected. The stomach was removed and fixed in 4% formalin for further analysis. The specimens were selected for the current study considering the species, site, capture date and different sizes. The number of size classes was defined to avoid the low representation of the largest individuals within the population (Chipps & Garvey 2007). Thus, three size classes were defined according to their total length: A = Small (*I. labrosus* between 60.0 - 116.0 mm, n = 60 and *P. maculatus* between 49.0 - 149.6 mm, n = 94); B = Medium (*I. labrosus* between 116.1 - 186.0 mm, n = 78 and *P. maculatus* between 149.7-239.9 mm, n = 103) and C = Large (*I. labrosus* between 186, 1 - 256.0 mm, n = 30, and *P. maculatus* between 240.0 - 390.4 mm, n = 37).

In the laboratory, each selected stomach was opened in a gridded Petri dish under and then assigned its Repletion State (RS) in one of five stages: 0 = empty stomach; 1 = stomach 1% to 25% full; 2 = stomach 26% to 50% full; 3 = stomach 51% to 75% full and 4 = stomach above 76% full. Stomach contents were analysed using the volumetric (quantitative) and frequency of occurrence (qualitative) methods proposed by Hynes (1950). For this, food items of each stomach were identified and quantified under optical microscope, whose volume was fractionated within the RS value and later grouped into categories. The volumetric data tabulation provided information for the calculation of frequency of occurrence. The use of cumulative prey curves determined the number of stomachs with food to be analysed (Chipps & Garvey 2007) and adding the stomach without food, at the end 176 specimens of *I. labrosus* and 255 of *P. maculatus* were used.

3. *Data analysis*

In order to analyse the diet of the two species and the influence of biotic (Species and Size class) and abiotic factors (Season and Site) the PERMANOVA analysis (Anderson et al. 2008) was performed. In order to carry out this analysis, we first transformated the volume data to log (X + 1). After this, a similarity matrix was created using the Bray-Curtis index and the analytical design with hierarchical factors: Season (four levels, fixed); Site (three levels, random) nested in Season; Species (two levels, random) nested in Season and Site; and Size class (three levels, random) nested in Species. The relative importance of each category was presented for PERMANOVA significant results through the Alimentary Index (AIi) (Kawakami & Vazzoler 1980):

$$AI_i = \frac{F_i \times V_i}{\sum_{i=1}^{L} F_i \times V_i}$$

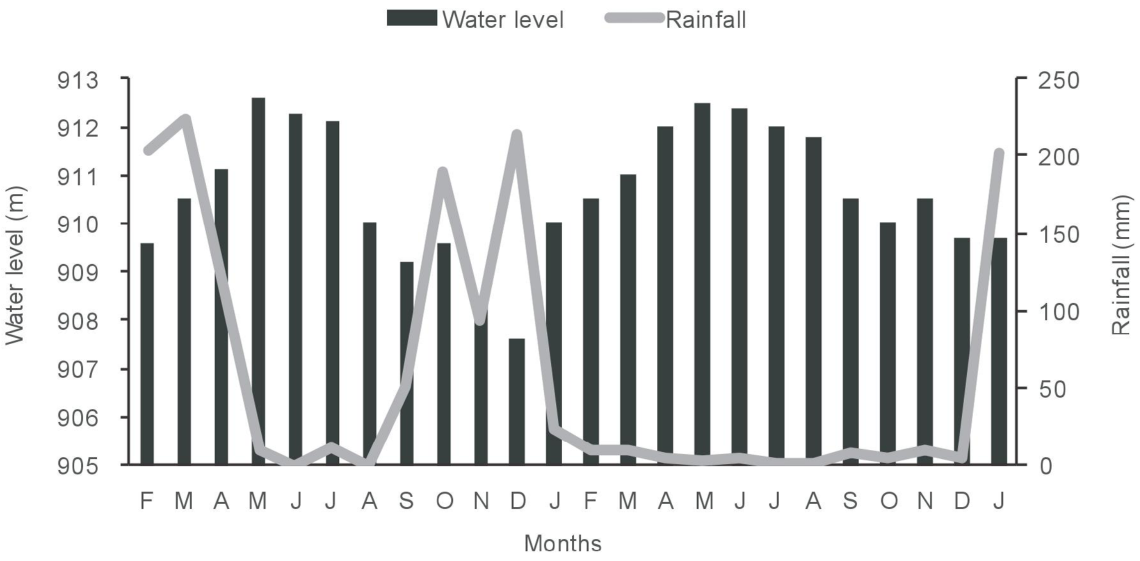

Figure 1. Rainfall and water level from February 1991 up to January 1993 at Camargos reservoir, MG, Brazil

Table 1. Site description, Camargos reservoir, MG, Brazil

Site	Distance from the dam (km)	Channel/ Margin	Maximum depth (m)	Mean depth (m)	Environment	Surrounding area
1	1	Main channel/left margin	18.6	7.4	Lentic	Degraded native pasture
2	7	Side channel/right margin	13.8	5.4	Backwater/ lentic	Group of vacation homes, few banks of aquatic plants; small riparian and semideciduous forest
3	13	Main channel/right margin	16.2	7.2	Temporally lotic	Permanent tributary; small riparian and semideciduos forest

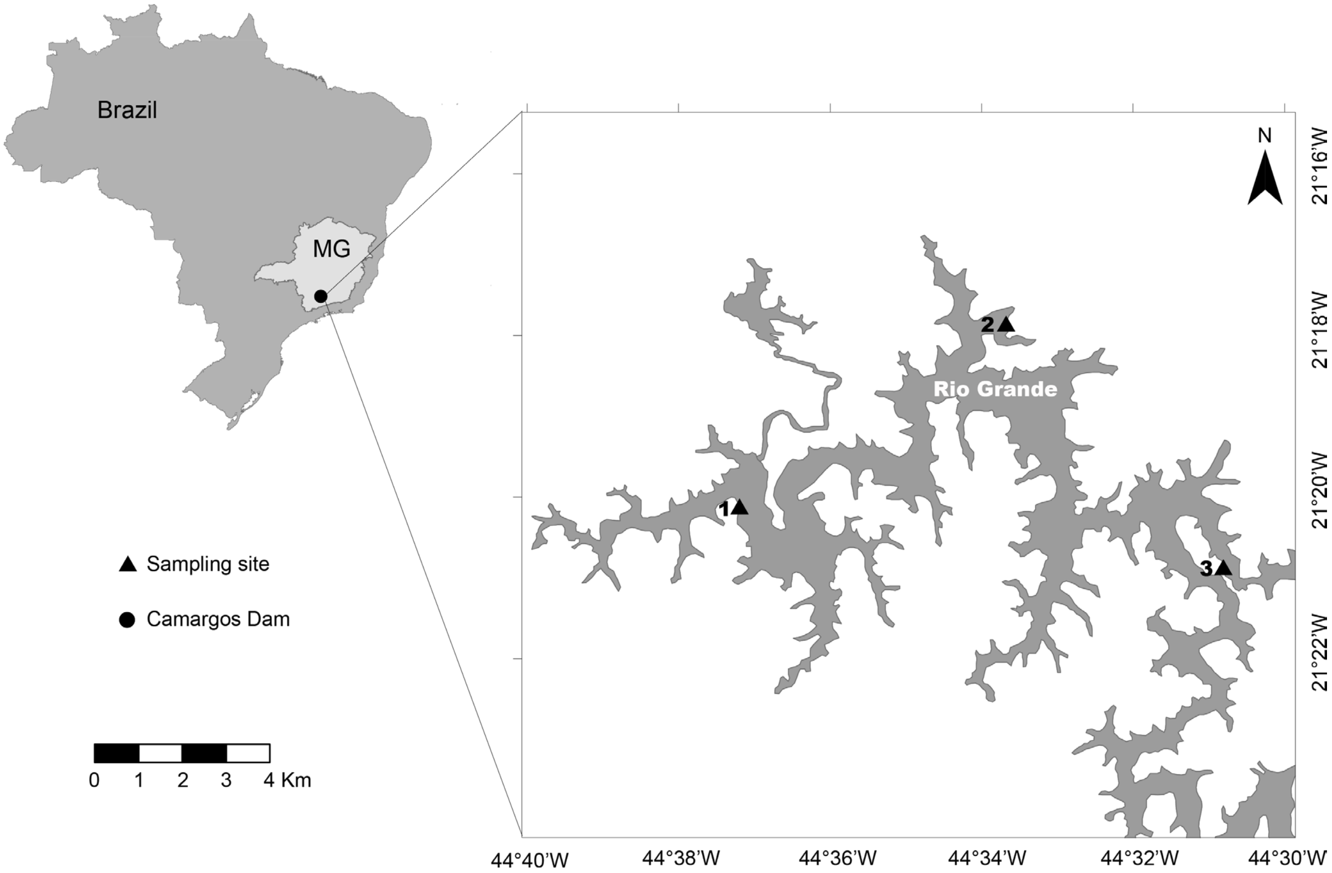

Figure 2. Map of study region showing sampling sites (1, 2 and 3), along Camargos reservoir, MG, Brazil

where $i = 1, 2, 3, \ldots$ n given food category; L= number of categories; Fi = Frequency of occurrence of category i (%) and Vi = relative volume of category i (%). Resource sharing was measured by the similarity of the species diet using Pianka Index (Pianka 1974):

$$O_{jk} = \frac{\sum_{i}^{n} P_{ij} P_{ik}}{\sqrt{\sum_{i}^{n} P_{ij^2} \sum_{i}^{n} P_{ik^2}}}$$

where Ojk = Pianka overlap measure between species j and k; Pij and Pik = Proportion of resource i in a total of resources used by species j and k, respectively and n = number total of categories. The visualization of food category responsible for the interspecific difference was done through the Non-metric multidimensional scaling (NMDS) analysis (Clarke & Gorley 2006).

Results

Camargos reservoir presented mean catch per unit effort (CPUE) of 11.8 individuals/100 m^2 of gill net/12h and 0.58 kg/100 m^2 of gill net/12h. *I. labrosus* and *P. maculatus* represented the first (36.1%) and third (9.1%) species most collected with gill nets.

Food was found in 119 of the 176 stomachs (67.6%) of *I. labrosus* and in 234 of the 255 stomachs (91.8%) of *P. maculatus*. While the proportion of empty stomachs increased throughout ontogeny in *I. labrosus*, this increase was not observed in *P. maculatus* (Fig. 3). The ingested items were grouped into eighteen food categories, seventeen of which were found in both species and greater diversity of items, within the categories, was recorded for *P. maculatus* (Table 2). Influences of the biotic and abiotic factors tested through PERMANOVA (Table 3) indicated that there were differences in diet associated with species (Pseudo F = 2.583, P = 0.001), size class (Pseudo F = 1.646, P = 0.001) and season (Pseudo F = 2.458, P = 0.006).

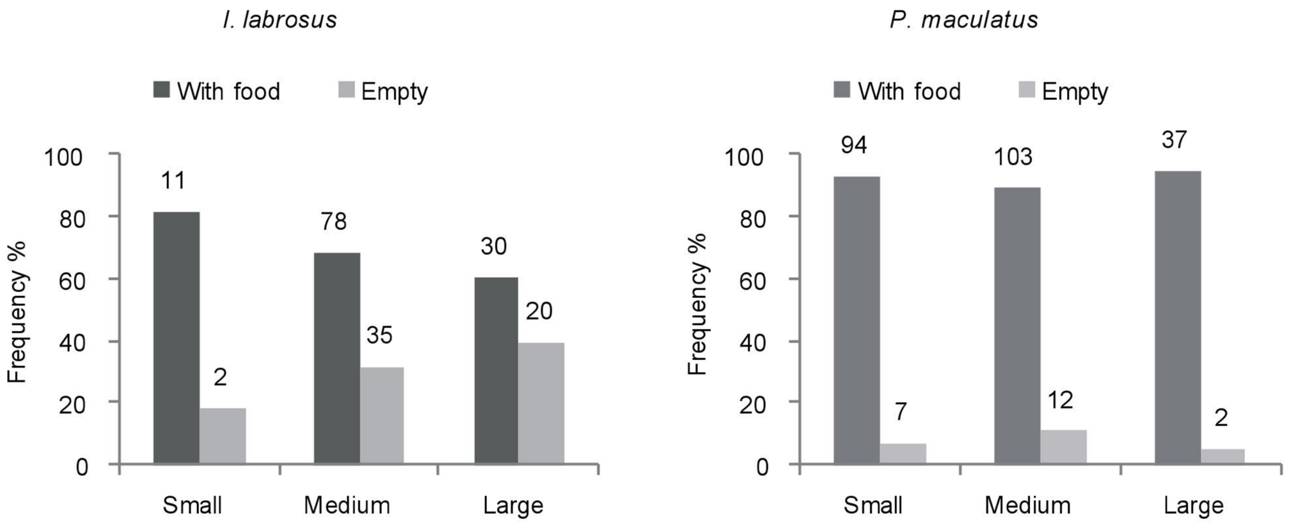

Figure 3. Percentage and number of stomachs with and without content in the three size classes of *I. labrosus* and *P. maculatus* at Camargos reservoir, MG, Brazil

Table 2. List of Identified taxa in the diet of *I. labrosus* and *P. maculatus* and their contribution in the frequency of occurrence (FO%) and volume (V%) at Camargos reservoir, MG, Brazil

Dietary categories/items	***Iheringichthys labrosus***		***Pimelodus maculatus***	
	FO%	**V%**	**FO%**	**V%**
ALGAE				
Actinotaenium sp.	0.84	< 0.001	1.71	< 0.001
Closterium sp.	2.52	< 0.001	0.85	< 0.001
Cosmarium sp.	1.68	< 0.001	2.56	< 0.001
Desmidium sp.	4.20	< 0.001	2.14	<0.001
Elakatotrix sp.	-	-	0.85	< 0.001
Hyalotheca sp.	8.40	0.36	16.24	0.57
Spirogyra sp.	10.08	0.62	8.12	0.50
Staurastrum sp.	1.68	< 0.001	1.28	< 0.001
Micrasterias sp.	1.68	0.002	1.28	< 0.001
Surirella sp.	-	-	2.14	< 0.001
TERRESTRIAL PLANTAE				
Echinolaena inflexa (seeds, leaf, stalk fragments)	48.74	6.12	37.18	6.94
Psidium guajava (seeds)	-	-	1.71	0.01
AQUATIC PLANTAE				
Cyperaceae, Apiaceae, Lentibulariaceae, Onagraceae (Petioles and leaf fragments)	8.4	0.81	53.85	8.86
PROTOZOA				
Difflugia sp.	38.66	0.46	2.56	0.08
ROTIFERA				
Keratella sp.	4.20	0.002	2.14	0.15
Notholca sp.	-	-	1.71	0.10
NEMATOIDA				
Nematoda (Ordem Dorylaimida)	44.53	1.04	33.76	1.14
Nematomorpha	0.84	0.42	2.14	0.29

Continuation Table 2.

Dietary categories/items	***Iheringichthys labrosus***		***Pimelodus maculatus***	
	FO%	**V%**	**FO%**	**V%**
ANNELIDA				
Tubificidae	2.53	0.29	1.71	0.63
Lumbriculidae	4.20	0.47	1.28	0.55
ACARINA				
Hydrachnellidae	21.01	0.28	12.82	0.27
Unsonicolidae	5.88	0.12	5.98	0.21
COPEPODA				
Mesocyclops sp.	41.17	5.78	22.22	2.83
Termocyclops sp.	21.01	4.49	32.48	4.84
Argyrodiaptomus sp.	4.20	0.40	2.14	0.17
CLADOCERA				
Daphnia sp.	16.83	1.83	12.39	0.53
Cariodaphnia sp.	3.36	0.90	5.56	0.12
Bosmina sp.	26.05	3.22	2.99	0.35
OSTRACODA	31.09	1.01	10.69	0.43
INSECTA				
Chaoboridae (larvae)	64.70	30.05	29.99	9.32
Chironomidae (larvae)	96.64	30.97	73.94	22.24
Other aquatic insect				
Ephemeroptera (larvae)	5.88	1.33	5.98	2.23
Odonata (larvae)	-	-	2.56	0.87
Neuroptera (larvae)	3.36	0.88	5.13	3.94
Tricoptera (larvae)	3.36	0.38	5.56	2.46
Ceratopogonidae (larvae)	30.25	4.68	19.66	3.40
Culicidae (larvae)	7.56	2.37	11.11	1.95
TERRESTRIAL ARTHROPODS				
Gryllidae	-	-	1.28	0.35
Isoptera	-	-	1.71	0.32
Hemiptera	-	-	1.71	0.59
Scarabaeidae	-	-	2.99	0.60
Elateridae	-	-	1.71	0.33
Tenebrionidae	-	-	0.43	0.17
Formicidae	-	-	2.14	0.43
Chaoboridae (adult)	3.36	0.36	0.85	0.33
Chironomidae (adult)	1.68	0.20	1.28	0.39
Phoridae	0.84	0.09	0.43	0.43
Aranae	-	-	2.14	0.32
FISH (Characiformes)	-	-	26.07	19.10
SCALE (isolated)				
scale cycloid	2.52	0.06	4.70	0.53
scale ctenoid	0.42	0.02	1.71	0.18

Table 3. Result of PERMANOVA analysis for use of food resources by *I. labrosus* and *P. maculatus* at Camargos reservoir, MG, Brazil

Sources	d.f.	SS	Pseudo-F	P (perm)	Uniq perms
Se	3	26298	2.458	0.006*	997
Sit (Se)	8	30356	0.562	0.981	997
Sp (Sit (Se))	11	78070	2.583	0.001*	999
Siz (Sp (Sit (Se)))	34	1.0876ES	1.646	0.001*	998
Res	296	5.7535ES			
Total	352	8.7055ES			

Sources: Se- Season; Sit: Site; Sp- Species; Siz- Size class; d.f.-degrees of freedom; SS- sum of squares; P (perm) -probabilility; uniq perms- permutations performed; * significant results.

Considering the Alimentary Index (AI - Table 4), it can be observed the dominance of invertebrate animal categories in the diet of *I. labrosus*, whereas in *P. maculatus* animal and vegetal categories presented a more even importance. Among the categories shared by the species, some variations relating to size classes and season can be highlighted. Both terrestrial and aquatic plants were important resources in the diet of smaller individuals of *P. maculatus* and also important for all size classes in the autumn and summer seasons. The microcrustaceans were more important in the diet of the smaller individuals for both species and in the seasons of winter and spring. With regards to insects, Chironomidae were more consumed by the smaller individuals of both species. Conversely, Chaoboridae were consumed in greater quantity by the larger individuals of both species, besides being the category of greater representation during the summer for *I. labrosus*.

The intraspecific and interspecific diet similarities were evidenced through the size classes, with the former presenting higher values (Table 5). Between the two species, diet similarities were observed in three of the four seasons, with higher values in winter. The differentiation among the species diet appears only during the summer. The food categories that most contributed to the differences among the species were Fish, Chaoboridae, Other aquatic insect, Chironomidae and Copepoda (Fig. 4).

Discussion

The Camargos reservoir has low fish productivity, even when compared to other Brazilian reservoirs (Agostinho et al. 2007). Our results allow the classification of *I. labrosus* and *P. maculatus* as invertivorous and omnivorous species, respectively. The largest population of *I. labrosus*, a invertivorous fish species in the Camargos reservoir, also differs from other Brazilian reservoirs (Agostinho et al. 2007), where the success of generalist species such as *P. maculatus* is widely reported in the literature (Agostinho et al. 2008) due to their greater colonization capacity (Sá-Oliveira et al. 2014).

The proportion of empty stomachs can also give information about the autoecology of the fish species (Vinson & Angradi 2011). In this way, the diet diversification of *P. maculatus* including the consumption of food with nondigestible fractions, such as vegetation (Vitule et al. 2008), reduces the proportion of empty stomachs in this species. In contrast, *I. labrosus* showed an increase in empty stomachs through ontogenetic development, since larger individuals seem to feed less frequently on larger prey (Vinson & Angradi 2011), as observed for Annelida and

Table 4. Dietary categories and their Alimentary Index (AI) for species, size class and season at Camargos reservoir, MG, Brazil. Values higher than 5% presented in bold, except sand not considered as food item.

Dietary categories	Alimentary Index (AI) for *I. labrosus*								Alimentary Index (AI) for *P. maculatus*							
	General	Small	Medium	Large	Summer	Autumn	Winter	Spring	General	Small	Medium	Large	Summer	Autumn	Winter	Spring
ALG	0.42	2.20	2.54	0.42	0.09	0.01	1.42	0.71	0.87	0.94	0.96	0.18	0.11	0.20	2.33	1.51
TPL	4.16	0.54	0.46	0.48	1.09	**10.17**	2.41	2.94	**5.92**	**5.56**	**6.54**	2.84	**9.64**	**9.95**	2.10	3.00
APL	0.10	0.05	0.04	0.08	0.32	0.15	0.03	<0.001	**10.11**	**10.26**	**9.85**	**7.04**	**15.37**	**8.28**	**10.27**	**5.97**
PRO	0.25	0.90	0.48	0.02	0.02	0.002	1.00	0.51	0.004	0.005	0.005	0.006	0.002	0.003	0.005	-
ROT	<0.001	<0.001	<0.001	-	-	<0.001	-	<0.001	0.02	0.01	0.05	0.08	0.002	0.02	0.04	0.03
NEM	0.93	3.28	2.57	0.18	1.41	0.15	0.25	1.12	1.19	0.94	1.70	0.19	1.34	0.68	2.66	0.40
ANN	0.07	0.008	0.79	**12.14**	0.12	-	0.20	0.08	0.08	0.01	0.02	1.66	0.02	-	0.16	0.17
ACA	0.15	0.35	0.48	0.005	0.03	0.06	0.42	0.17	0.20	0.39	0.14	-	0.09	0.21	0.17	0.33
COP	**9.88**	**32.37**	**11.44**	**5.05**	1.37	**6.37**	**17.06**	**20.13**	**9.78**	**13.34**	**9.63**	0.45	**7.21**	2.49	**14.09**	**21.91**
CLA	3.84	**16.95**	**5.29**	2.02	0.10	4.79	**9.49**	2.81	0.46	0.88	0.29	0.007	0.12	0.24	1.24	0.13
OST	0.44	0.07	0.12	0.02	0.10	0.38	0.91	0.41	0.10	0.27	0.03	0.01	0.15	0.06	0.15	0.03
CHA	**27.13**	**14.85**	**56.74**	**60.25**	**67.00**	**21.93**	4.90	**17.53**	**5.90**	4.89	**6.69**	4.43	**6.61**	2.82	3.07	**17.97**
CHI	**41.76**	**21.78**	**13.78**	**13.65**	**17.84**	**44.64**	**51.52**	**44.84**	**34.48**	**36.25**	**38.88**	**6.90**	**30.40**	**40.53**	**39.70**	**13.70**
OAI	2.61	0.28	0.95	2.03	2.26	3.76	3.11	0.70	**15.84**	**11.38**	**16.54**	**25.27**	**19.75**	**15.25**	**8.69**	**22.47**
TAR	0.02	<0.001	<0.001	0.02	0.009	0.01	0.09	-	1.55	0.75	1.60	**5.14**	0.74	1.92	0.64	3.03
FIS	-	-	-	-	-	-	-	-	**10.90**	**11.39**	4.53	**44.86**	**5.22**	**15.22**	**11.89**	**7.74**
SCL	0.002	0.06	<0.001	<0.001	-	0.01	-	<0.001	0.12	0.29	0.04	0.02	0.28	0.15	0.03	0.09
SAN	8.25	6.30	4.33	3.61	8.23	7.56	7.20	8.07	2.44	2.44	2.49	0.91	2.95	1.98	2.78	1.53

Codes: ALG: Algae; TPL: Terrestrial plantae; APL: Aquatic plantae; PRO: Protozoa; ROT: Rotifera; NEM: Nematoida; ANN: Annelida; ACA: Acarina; COP: Copepoda; CLA: Cladocera; OST: Ostracoda; CHA: Chaoboridae; CHI: Chironomidae; OAI: Other aquatic insect; TAR: Terrestrial arthropod; FIS: Fish; SCL: Scale and SAN: Sand.

Table 5. Pianka's Index of diet similarity to species, size class and season at Camargos reservoir, MG, Brazil

	***I. labrosus*- Small**	***I. labrosus*- Medium**	***I. labrosus*- Large**	***P. maculatus*- Small**	***P. maculatus*- Medium**
I. labrosus- Small					
I. labrosus- Medium	**0.61**				
I. labrosus- Large	0.44	**0.97**			
P. maculatus- Small	**0.66**	0.37	0.32		
P. maculatus- Medium	**0.62**	0.39	0.35	**0.97**	
P. maculatus- Large	0.09	0.12	0.13	0.50	0.42
I. labrosus and *P. maculatus*	Summer	Autumn	Winter	Spring	
	0.37	**0.82**	**0.91**	**0.66**	

High significant overlaping > 0,6 (Novakowski et al., 2008) in bold.

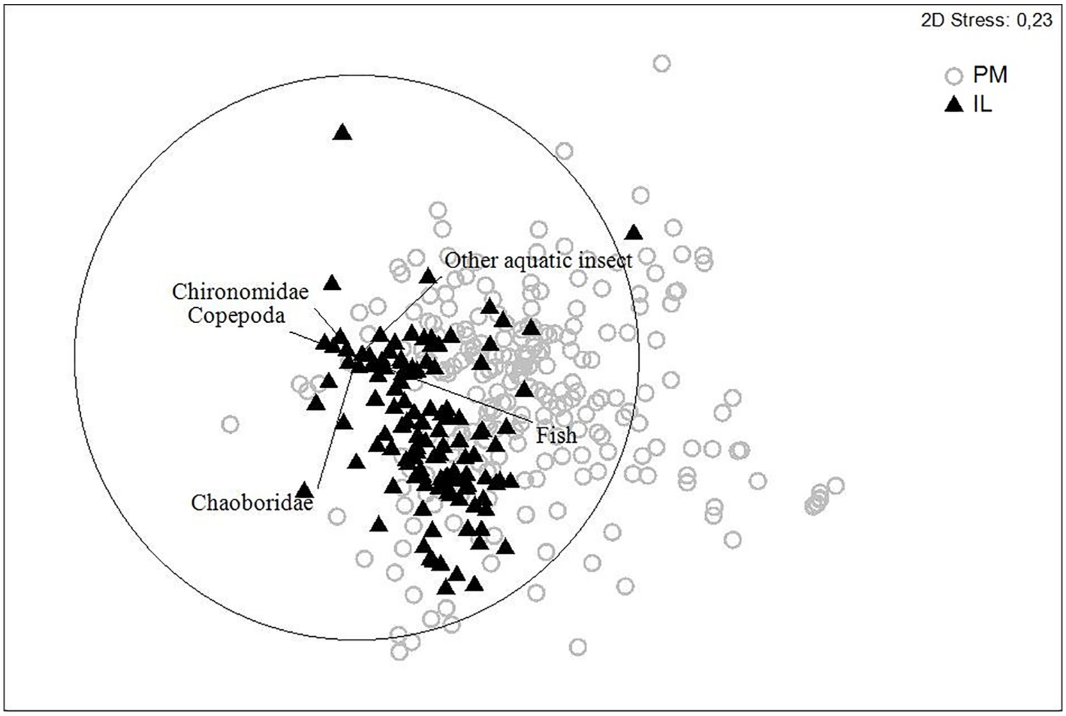

Figure 4. Non-metric multidimensional scaling (NMDS) showing the food resources responsible for the difference between the species *I. labrosus* and *P. maculatus* at Camargos reservoir, MG, Brazil

Chaoboridae. Arrington et al. (2002) also observed a greater number of empty stomachs in invertivorous than omnivorous fish.

The spatial scale considered in this study may be responsible for the higher values of biotic factors in the difference between diets, since large-scale studies are more effective in emphasising the regulation of abiotic factors in fish communities (Jackson et al. 2001). Changes in the diet during ontogenetic development reinforce the statement of Vitule et al. (2008) that species may not be an adequate analysis unit per se and ontogeny also need to be evaluated when food habits are compared among species that live in the same area. As for the abiotic factors, the ability to change seasonally the digestive morphology such the intestinal length, intestine weight, and liver weight has already been reported in *I. labrosus* (D'Anatro et al. 2013). In some species, these changes are reversible and reached in a few days in response to nutritional variations (Gaucher et al. 2012).

In the present study, *I. labrosus* and *P. maculatus* showed a diversified diet based on benthic items that corroborate other studies (Basile-Martins et al. 1986, Abes et al. 2001, Fugi et al. 2001, Andrade & Braga 2005, Ribeiro et al. 2014). The categories Sand and Scale (isolated) should not be considered as part of the diet, but rather as an involuntary intake and confirmation of feeding in the benthic zone as occurred in other fish species that search prey near the bottom (Atobatele & Ugwumba 2011). Despite this, it is important to note that not only benthic items were found in the stomachs of the studied species. The ingestion of microcrustaceans, Chaoboridae and allochthonous resources indicates the use of the limnetic zone (Câmara et al. 2012) and marginal areas of the reservoir (Agostinho et al. 2008). Feeding habitat expansion was also observed by Dill (1983) and justify by food limitation. Among the studied species, *I. labrosus* was more associated to the benthic environment in feeding (Abes et al. 2001) and ecomorphology (Teixeira & Bennemann 2007, Masdeau et al. 2011) studies than *P. maculatus*, which has already been associated with different trophic levels (Lobón-Cerviá & Bennemann 2000).

Our results demonstrated less resource sharing among the species in period of greater trophic abundance, as in the studies of Prejs & Prejs (1987) and Meschiatti (1995). However, we emphasize that this occurred exclusively in the summer and not during the entire rainy season. The reason for this may be the lack of correspondence between natural periods of drought and rainfall with the low and high levels in reservoirs (Silva et al. 2008), as shown in Fig. 1. The greater richness and abundance values of aquatic insects in reservoir in the rainy-warm season (Câmara et al. 2012) was associated with the increase in water levels, greater external material input and greater habitat heterogeneity (Santana et al. 2015). This occurred in the summer, but not in the spring, which is the season with lowest level of the Camargos reservoir. In addition, the two dry seasons of autumn (where the level of the reservoir is at its highest) and winter had lowest presence of Chaoboridae and Other aquatic insect. This caused the higher intake of common prey such as Chironomidae and Copepoda and greater similarity between diets. The pressure of similar diet in three out of four seasons was reduced by the interspecific diet difference, which was found along the ontogeny. This phenomenon has already been recorded in fish by Frehse et al. (2015) and described as part of a strategy to reduce competition and allow coexistence among related species.

Contextualizing the studied environment during the collection period, which began forty years after its construction, the characteristics of few macrophytes and oxygenated hypolimnion help to explain the relative importance (AI) of the Chaoboridae found, which differs from studies that show greater presence and importance of Chironomidae in reservoirs (Abes et al. 2001, Callisto et al. 2002, Costa et al. 2006, Silva et al. 2015). As the Camargos reservoir ages, *I. labrosus*, a species with a less diversified and invertivorous diet, is shown to be successful and competitive (Mérona et al. 2003). This may be related to the fact that *I. labrosus* has a lower body mass and uses less allochthonous resources than *P. maculatus*, a relevant fact in a reservoir with scarce marginal vegetation. Thus, the long period of diet overlap between two of the most fished species and the low fish productivity may indicate the limitation of resources in this reservoir and should be considered from an ecological perspective for future plans of new upstream reservoir construction. In addition, the autochthonous and allochthonous food categories with high common use or low values are supporting information to optimize management and best use of this reservoir.

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Author Contributions

Zoraia Silva: performed data collection, data analysis and interpretation and writing of the manuscript;

Patrícia Elaine Cunha do Nascimento: data collection and analysis and manuscript preparation.

Jean Ricardo Simões Vitule: data analysis, critical revision and adding intellectual content.

Fabrício de Andrade Frehse: data analysis, critical revision and adding intellectual content.

Mayara Silva Oliveira Ferraz: data analysis and interpretation and manuscript preparation.

Lea Rosa Mourgués-Schurter: contribution in the concept, design of the study and data collection.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Article

Aspects of mating behavior and antennal sensilla in *Anomala inconstans* Burmeister, 1844 (Coleoptera: Scarabaeidae: Rutelinae)

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Abstract: When suitable, adults of Scarabaeidae usually form swarms to find food and breeding sites. The steps of mating behavior can be mediated by chemical communication, and antennal sensilla are released volatiles detection structures, as sexual pheromones. In present work the mating behavior and the antennal sensilla of *Anomala inconstans* Burmeister, 1844 are described. The study was conducted at the Universidade Estadual de Mato Grosso do Sul, Cassilândia, Brazil from March 2015 to December 2017. Adults were collected through a light trap and taken to the laboratory for studies. Field and laboratory observations provided data for the description of the steps of mating behavior. Adults swarms were registered from September to November 2015 at 05:30 pm to 00:00 am. Females display a calling behavior from 05:25 pm to 08:00 pm, in which they rub their posterior legs against their abdomen, and after a few minutes males are able to locate them. In laboratory, the mating process lasted 20.4 minutes on average, and the possibility of chemical communication between adults was here discussed. The antennae of the species have trichoid, chaetica, placoid types I, II and III, and coeloconic types I and II sensilla. Placoid sensilla are the most abundant and females have more sensilla than males.

Keywords: *Anomalini, chemical communication, chemical receptors, Neotropical, Scarabaeoidea.*

Aspectos do comportamento de cópula e sensilos antenais em *Anomala inconstans* Burmeister, 1844 (Coleoptera: Scarabaeidae: Rutelinae)

Resumo: Em condições adequadas os adultos de Scarabaeidae geralmente realizam revoadas em busca de alimento e áreas de reprodução. As etapas relacionadas ao comportamento de cópula podem ser intermediadas por comunicação química, e os sensilos antenais são as estruturas que detectam os voláteis como os feromônios sexuais. No presente trabalho o comportamento de cópula e os sensilos antenais de *Anomala inconstans* Burmeister, 1844 são descritos. Os estudos foram conduzidos na Universidade Estadual de Mato Grosso do Sul, Cassilândia, de março de 2015 a dezembro de 2017. Adultos foram coletados com armadilha luminosa e conduzidos para laboratório para estudos. Observações de campo e de laboratório permitiram a descrição das etapas do comportamento de cópula. Os adultos revoaram de setembro a novembro de 2015 das 17:30h as 24:00h. As fêmeas apresentam o comportamento de chamamento das 17:25h as 20:00h, no qual atrita o terceiro par de pernas no abdome e, transcorridos alguns minutos, os machos as localizam. Em laboratório a cópula durou em média 20,4 minutos, sendo verificada a possibilidade de comunicação química entre os adultos. Nas antenas foram encontrados sensilos tricódios, chaéticos, placódios dos tipos I, II e III, e coelocônicos tipo I e II. Os sensilos placódios são os mais abundantes, e as fêmeas possuem mais sensilos do que os machos.

Palavras-chave: *Anomalini, comunicação química, receptores químicos, Neotropical, Scarabaeoidea.*

Introduction

Phytophagous scarab beetles (Coleoptera: Scarabaeidae) in Neotropical region usually swarm during the hot and humid period of the year, when they can be observed feeding on leaves, flowers and fruit of several plant species (Oliveira & Ávila 2011, Gottsberger et al. 2012, Martínez et al. 2013, Moore & Jameson 2013, Ferreira et al. 2016, Rodrigues et al. 2016). The different plant species used for feeding are important breeding sites for Scarabaeidae (Morón 1996, Maia & Schlindwein 2006, Rodrigues et al. 2017).

The mating process of Scarabaeidae can be subdivided into steps. Initially, adults land on plants after swarming, attracted by plant volatile chemicals (Stensmyr et al. 2001, Ruther 2004). Then, females exhibit a calling behavior and release a sexual pheromone to attract males (Tada & Leal 1997, Facundo et al. 1999, Robbins et al. 2009). At that moment, males can locate females and initiate chemical recognition processes, after what females select males to mate (Fávila 1988).

Adult Scarabaeidae locate and recognize plant volatiles and female pheromones through antennal sensilla, which are quite diverse (Larsson et al. 2001, Ochieng et al. 2002, Romero-López et al. 2004, 2010, Romero-López 2016).

Some species of Scarabaeidae might be regarded as important crop pests in Brazil (Oliveira et al. 2007, Santos & Ávila 2007, Coutinho et al. 2011). Among such species, *Anomala inconstans* Burmeister, 1844 (Rutelinae, Anomalini) has been observed developing in corn (*Zea mays* L.) (Poaceae) crops (Rodrigues et al. 2011). In Colombia, larvae of this species were reported damaging roots of pasture, cassava (*Manihot* sp.) (Euphorbiaceae), coffee (*Coffea* sp.) (Rubiaceae) and wild plants (Pardo-Locarno et al. 2005). Immature *A. inconstans* was described by Ramírez-Salinas et al. (2004).

Present study proposes to describe the antennal sensilla and mating behavior of *A. inconstans* based in material collected in pasture areas in Cassilândia, Mato Grosso do Sul, Brazil.

Material and Methods

The study was conducted at the Universidade Estadual de Mato Grosso do Sul (UEMS), Campus of Cassilândia. Adults of *A. inconstans* were collected using a light trap model "Luiz de Queiroz" from March 2015 to December 2017. The trap was installed in a pasture area (*Brachiaria decumbens* Stapf cv. Basilisk, Poaceae), was turned on daily at 05:00 pm and turned off at 6:00 am of the next day. Insects were collected every 60 minutes (methodology by Rodrigues et al. 2014).

Data of average temperature (°C), rainfall (mm) and solar radiation (KJ/m^2) in Cassilândia were obtained from the website of the Instituto Nacional de Meteorologia (INMET: http://www.inmet.gov.br/portal/).

Observations of the mating behavior were conducted from October to November of 2015 and 2016. Adults collected were sexed and individually placed into 1,000 ml plastic containers, containing about 666 ml of soil collected from pasture area and covered with voile fabric. The behavior of adults was observed during the evening, when they emerged from the soil. Males and females were brought together after they left the soil. Thirty-four couples were formed to allow mating behavior observations (methodology adapted from Rodrigues et al. 2014).

From September to November 2017, behavior observations were carried out in the UEMS pasture area with *B. decumbens* grass, from 05:00 to 08:00 pm. During this period, high temperatures and high humidity were observed in the studied region.

The study of antennal sensilla was based in antennal clubs of 10 dissected specimens. Images were taken by a scanning electron microscope (model JSM 5410) from the Laboratório de Microscopia Eletrônica of the Universidade Estadual Paulista, campus of Jaboticabal, São Paulo State. Sensilla terminology follows Keil (1999). Meinecke (1975) was used as an alternative sensilla terminology (in brackets) to easily term comparison.

The antennal lamellae were also mounted on slides for optical microscope observation. Antennal segments were formerly treated in a 10% potassium hydroxide solution at 80°C for 60 minutes. The pieces were then successively washed in distilled water, 70% ethanol, 80% ethanol, and 90% ethanol, respectively. After that, the material was cleared in xylene for 10 minutes. Finally, the lamellae were mounted on slides with Hoyer's solution (Johnson & Triplehorn 2005) replacing the Canada Balsam as described by Romero-Lopez et al. (2004) and then observed under a Nikon microscope model E2000. The insects were deposited in the UEMS insects collection, campus of Cassilândia, MS.

Results

Mating behavior. Adults were collected using a light trap from September to November 2015. Fifty specimens were collected in September, 61 in October, and 9 in November. They were collected from 05:30 pm to 00:00 am (Figure 1). From 05:00 to 06:00 pm, brightness decreases from 10.76 KJ/m^2 to 0.0 KJ/m^2 (Figure 2) and beetles started to fly when it is dark. The highest number of adults was obtained from 06:00 to 07:00 pm where the average temperature was 26.4^{o}C (Figure 2). From 07:00 pm onwards, was a decrease in the number of adults collected and after 11:00 pm they stopped appearing.

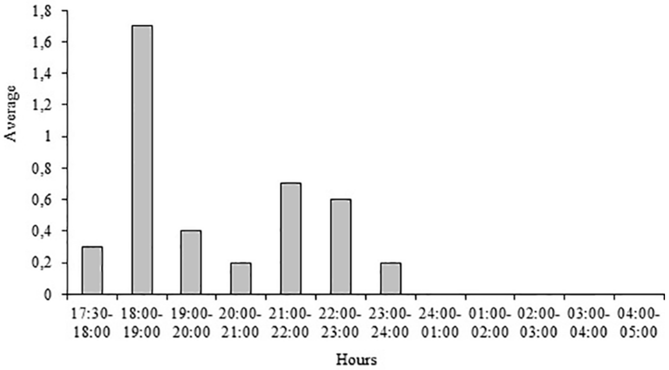

Figure 1. Adult *Anomala inconstans*, collected through a light trap. Data from September 29 to October 2, 2015. Cassilândia, MS, Brazil.

Laboratory observations showed that during the day, adult of *A. inconstans* remained under the soil. After dark, from 06:00 pm onward, adults initially project a small portion of their clypeus near soil surface and then leave the soil completely.

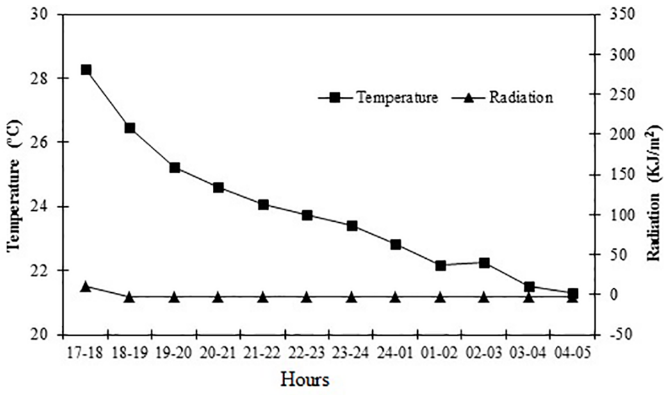

Figure 2. Average temperature (°C) and radiation (KJ/m^2), obtained from meteorological station (INMET).

Females actively walk or fly for 5.12 ± 0.37 (2-9) minutes after they leave the soil (n = 34), then they decrease their activity, stand still, and start rubbing their posterior legs against their abdomen (n = 10). Males walk or fly for 8.62 ± 0.47 (4-14) minutes after they leave the soil (n = 34), and then stand still.

After adults decreased their activity, 34 couples were formed. Of the 34 couples formed, 26 did not mate, so only eight couples presented the steps related to mating behavior. On one occasion, the male approached the female, extroverted its aedeagus, but it was rejected by the female.

The eight formed couples, show several steps that resulted in mating (Figure 3). Initially, adults touched each other with their clypeus while their antennae kept moving and lamellae remained open. Then, males positioned themselves on top of females, extroverted their aedeagus, and began copulation.

Copulation lasted 20.4 ± 0.86 (17-25) minutes. After copulation, males remained over females for 27.62 ± 2.97 (20-45) seconds, after which they detached themselves from females and flew or walked on the soil. This last step lasted 120 ± 9.93 (95-180) seconds. Finally, free females buried themselves into soil. Apparently, chemical recognition occurred during the aforementioned process.

Adults were observed flying over pasture from 05:20 pm onwards. Females left the ground, flew and landed on shrubs in the pasture. Females flew between 20 and 120 cm high, after which they initiated their male calling activity (n = 23). The calling behavior was initiated through the rubbing of the metafemur and tibiae against their abdomen (Figure 4). Then it was observed that males detect females while flying, land near them, walk toward them, and immediately begin copulation. Copulation lasted 26.61 ± 0.36 (24-29) (n = 23) minutes.

Antennal sensilla. Trichoid, chaetica, placoid and coeloconic sensilla were found on the lamellae. Chaetica sensilla are long and thin, and trichoid sensilla are short and thin (Figure 5A). These sensilla are observed on the outer surface of club, especially the trichoid ones.

Placoid sensilla (types I, II and III) and coeloconic sensilla (types I and II) are located on the inner surface of proximal lamella, on outer and inner surfaces of the middle lamella, and on the inner surface of distal lamella. On the outer surface of distal lamella there are placoid sensilla, but no coeloconic sensilla, which are found in the proximal half of inner surface (Figure 5B). Placoid sensilla occur in the various areas of the lamellae, however, basiconic sensilla occur in the anterior third of the lamellae (Figure 5C).

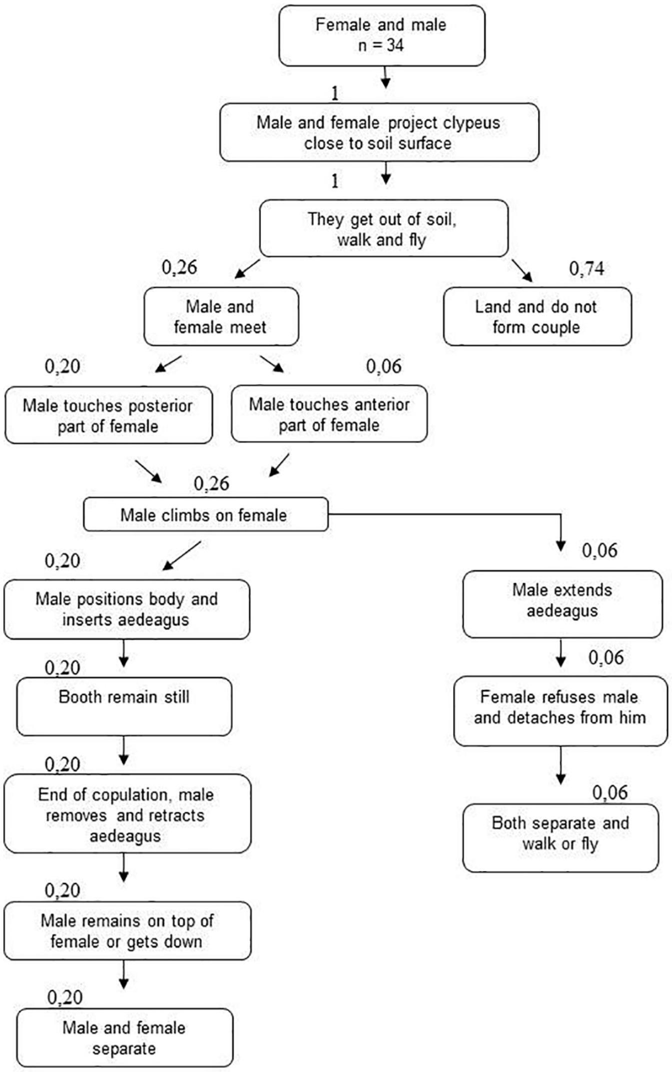

Figure 3. Ethogram of mating behavior of *Anomala inconstans*, in laboratory.

Figure 4. Calling behavior and potential release of sexual pheromone of female *Anomala inconstans*.

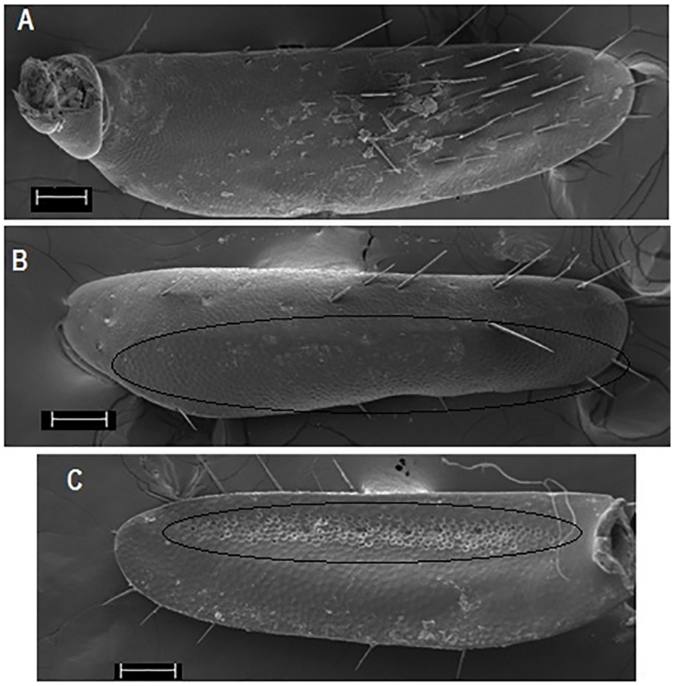

Figure 5. Antenna lamellae of *Anomala inconstans*. 5A) Trichoid and chaetica sensilla on outer area of proximal lamella. 5B) Placoid sensilla on outer distal lamella. 5C) Placoid and coeloconic sensilla on anterior third of lamella. Scale 100 micrometers.

Placoid sensilla types I, II and III were found. Type I placoid sensilla (H1 classification by Keil 1999) have an irregular shape with surface undulations and a mean diameter of 12.18 µm (10-14) (Figure 6). Type II placoid sensilla (G1 classification of Keil 1999) have irregular shape, high edges, deeper undulations than type I, and a mean diameter of 6.45 µm (5.6-7.6) (Figure 6). Type III placoid sensilla (H3 classification of Keil 1999) have an irregular shape, flat surface, and a mean diameter of 12.6 µm (11.2-16) (Figure 6).

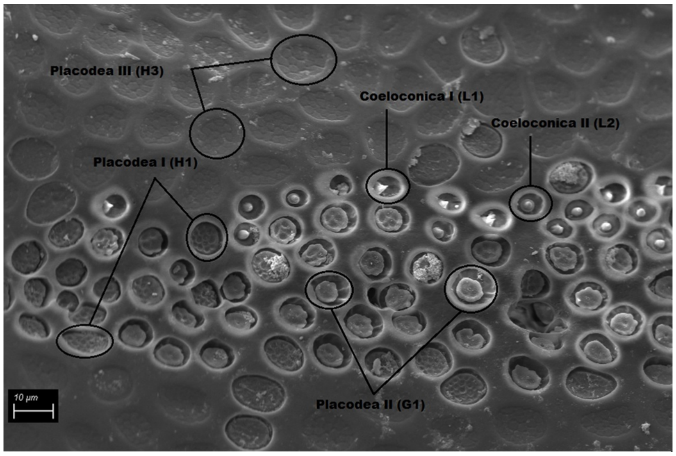

Figure 6. Placoid sensilla I, II and III, and coeloconic sensilla I and II on antennae of *Anomala inconstans*.

Coeloconic sensilla were classified as type I (L1 classification of Keil 1999) with acute apex, and type II (L2 classification of Keil 1999) with slightly dilated apex.

In females (n = 10), 7784 sensilla were quantified, 234 (3.04%) of which are coeloconic and 7547 (96.96%) placoid (Table 1). In males (n = 10), 5741 sensilla were quantified, 176 (3.06%) of which are coeloconic and 5565 (96.94%) placoid (Table 1). Placoid sensilla are the most abundant in both sexes, and females have more sensilla than males.

Discussion

In present study, adult *A. inconstans* were collected from September to November. Other Scarabaeidae species also swarm for a short period of time in the field, as observed in *Liogenys suturalis* Blanchard, 1851 (Melolonthinae) (Santos & Ávila 2009) and *Geniates borelli* Camerano, 1894 (Rutelinae) (Rodrigues et al. 2012).

Steps related to the mating behavior of *A. inconstans* are similar to those described by Rodrigues et al. (2014) for *Anomala testaceipennis* Burmeister, 1856. During the steps of the mating behavior, some female *A. inconstans* did not accept males for copulation, demonstrating male selection. This behavior was also observed in *A. testaceipennis* (Rodrigues et al. 2014), *Cyclocephala verticalis* Burmeister, 1847 (Dynastinae) (Barbosa & Rodrigues 2016) and *Leucothyreus albopilosus* Ohaus, 1917 (Rutelinae) (Ferreira et al. 2016).

Observations made both in the laboratory and in the field demonstrated an intense activity of the antennae during several moments of copula. In laboratory, adults kept their antennae raised and made small movements with their lamellae open. In the field, females displayed a calling behavior and in few minutes a male would find them, and the couple would copulate.

Chaetica and trichoidea sensilla are found in outer side of club (inner side of proximal lamella, outer and inner sides of medial lamella, inner side of distal lamella). Keil (1999) describes chaetica and trichoidea sensilla as mechanoreceptors and contact chemoreceptors (gustative, mainly sensilla trichoidea). Sensilla chaetica are also found in other antennomeres.

Antennal lamellae of *A. inconstans* displayed placoid and coeloconic sensilla in the anterior third and placoid sensilla in the other areas. The sensilla types and distribution patterns in *A. inconstans* are similar to those characterized in other Rutelinae (Ågren 1985: *Phyllopertha horticola* (Linnaeus, 1758); Hansson et al. 1999: *P. diversa* Waterhouse, 1875; Kim & Leal 2000: *Popillia japonica* Newman, 1841; Lu & Wang 2009: *Proagopertha lucidula* (Faldermann, 1835); Mutis et al. 2014: *Hylamorpha elegans* (Burmeister, 1844); Leal & Mochizuki 1993: *Anomala cuprea* (Hope, 1839); Yao et al. 2004 and Song et al. 2012: *A. corpulenta* Motschulsky, 1854). This pattern is formed by a lateral lamellar area with sensilla placodea without ditch (type III; Meinecke 1975: H3) and a central longitudinal groove (anteriorly positioned in *A. inconstans*) bearing sensilla placodea with ditch (type I; Meinecke 1975: H1, H2), flattened sensilla placodea (type II; Meinecke 1975: G1), acute sensilla coeloconica (type I; Meinecke 1975: S1) and rounded sensilla coeloconica (type II; Meinecke 1975: S2).

Table 1. Sensilla on antennal lamellae of *Anomala inconstans*.

Sensillum	Proximal lamella		Middle lamella		Distal lamella		Total
	outer	inner	outer	inner	outer	inner	
				Female			
Coeloconic	0	83	31	46	0	77	237
Placoid	0	1721	967	1650	1303	1906	7547
Total	0	1804	998	1696	1303	1983	7784
				Male			
Coeloconic	0	40	29	21	0	86	176
Placoid	0	1249	1226	1081	892	1117	5565
Total	0	1289	1255	1102	892	1203	5741

In *Phyllopertha dispersa*, all sensilla placodea and coeloconica are pheromone detecting structures, while sensilla of inner groove are both sexual pheromone and plant volatile detecting structure (Hansson et al. 1999).

Kim & Leal (2000) suggested that the distribution sensilla pattern and sexual differences (sensilla abundance in male and female) are related with mate searching behavior intermediated by sexual pheromones in Rutelinae.

According Larsson et al. (2001) study of *A. cuprea*, the placoid sensilla of peripheral area of lamellae are responsible for detecting sexual pheromones, while sensilla in the central part detect plant volatiles and other odors. Otherwise, Sun et al. (2014) suggested that sensilla placodea was plant volatile main receptor and coeloconica as sexual attractant receptor to *Holotrichia oblita* (Faldermann, 1835) (Melolonthinae).

In concordance with above mentioned suggestions, Li et al. (1995) found that some Rutelinae (*A. corpulenta*, *Popillia atrocoerulea* Bates, 1888, *P. quadriguttata* (Fabricius, 1787)) are strong influenced by sexual attractant, while other phytophagous Scarabaeidae are more sensitive to food odorants or aggregative pheromones.

Sexual pheromones are not the only semiochemicals identified in scarab beetles. Some Dynastinae present aggregative attractants (Renou et al. 1998, Kim & Leal 2000). To *Anomala* Samouelle, 1819, sexual pheromones were described, but not aggregative chemicals (c.f. Wang & Sun 2005).

Sexual pheromone producing tissue are seldom reported to scarab beetles. Kim & Leal (1999) and Romero-Lopez et al. (2011) found melolonthine beetles (*Phyllophaga obsoleta* (Blanchard, 1850) and *Holotrichia paralela* (Motschulsky, 1854), respectively) bearing eversible glands in the terminalia that are extroverted during sexual calling and are related to pheromone production. In other melolonthine, *Costelytra zealandica* (White, 1846), females produce possible sexual attractants in their genital accessory glands in association with symbiotic microbes (Hoyt et al. 1971). Within *Anomala*, the pheromonal producer tissue is known to *Anomala albopilosa albopilosa* (Hope, 1839), in which sexual pheromone is produced in epithelial cells of the pygidium and last two ventrites, and these cells are linked with surface through puncture (Tada & Leal, 1997). If the terminalia cells of other *Anomala* are considered as pheromone producer, as in *A. albopilosa albopilosa*, this could elucidate why attracted males touch female pygidium and abdomen with its antenna in matting process (Figure 3).

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Author contributions

Sérgio Roberto Rodrigues: Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

Juares Fuhrmann: Contribution in the analysis and interpretation of data, also assisting in article revision, adding intellectual content.

Ricardo Aparecido Amaro: Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Inventory

Checklist of the flora in ironstone outcrops at the Urucum Plateau, Corumbá, Mato Grosso do Sul

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Abstract: "Cangas" are ironstone outcrops occurring at the foot of the Urucum Plateau, on the western edge of Pantanal, Corumbá-MS. In Brazil, the knowledge about flora and ecology of the plant communities associated with these formations is still incipient. These habitats are among the most threatened and less studied in Brazil because of their association with high quality iron ore deposits. We present a cheklist of the flora from these formations, resulting from different authors' collecting efforts in 10 areas of the Plateau. A total of 302 species have been recorded; they were distributed in 53 botanical families and 175 genera. Poaceae (43 species), Fabaceae (41), Euphorbiaceae (22), Cyperaceae (19), Malvaceae (19), Convolvulaceae (15), Malpighiaceae (13) and Apocynaceae (11) accounted for 60.6% of the species richness. Our data add 59 new occurrences of species of angiosperms to the ironstone outcrops flora in the Urucum Plateau. Among these, 27 species had no occurrence record for Mato Grosso do Sul and three species had not yet been recorded for Brazil. The high diversity and presence of endemic, rare, endangered and/or not yet cataloged species for the Urucum Plateau region, reinforces the need for local conservation units that can guarantee the preservation of these species, since the existing environmental protection areas are insufficient to guarantee the maintenance of typical species from this habitat in the region.
Keywords: *biodiversity, ferruginous geosystem, Pantanal.*

Checklist da flora de cangas do Maciço do Urucum, Corumbá, Mato Grosso do Sul

Resumo: As cangas são afloramentos ferruginosos que ocorrem ao sopé do Maciço do Urucum, na Borda Oeste do Pantanal, Corumbá-MS. No Brasil, o conhecimento sobre a florística e ecologia das comunidades vegetais associadas a essas formações ainda é incipiente. Esses habitats estão entre os mais ameaçados e menos estudados do Brasil, devido à sua associação a depósitos de minério de ferro de alta qualidade. Nós apresentamos um cheklist da flora desses ambientes, resultante de diversos esforços de coleta de diferentes autores em 10 áreas do Maciço. Foram registradas 302 espécies distribuídas em 53 famílias botânicas e 175 gêneros. Poaceae (43 espécies), Fabaceae (41), Euphorbiaceae (22), Cyperaceae (19), Malvaceae (19), Convolvulaceae (15), Malpighiaceae (13) e Apocynaceae (11) representaram 60,6% da riqueza específica. Nossos dados adicionam 59 novas ocorrências de espécies de angiospermas para a flora de cangas do Maciço do Urucum. Das espécies apresentadas, 27 ainda não possuíam registro de ocorrência para o Mato Grosso do Sul e três espécies não haviam sido ainda registradas para o Brasil. A alta diversidade e a presença de espécies endêmicas, raras, ameaçadas e/ou ainda não catalogadas para a região do Maciço do Urucum reforça a necessidade de unidades de conservação locais que possam garantir a preservação dessas espécies, uma vez que as áreas de proteção ambiental existentes na região são insuficientes para garantir a manutenção de populações típicas desse habitat.
Palavras-chave: *biodiversidade, geossistema ferruginoso, Pantanal.*

Introduction

Ferruginous geosystems are landscapes of great value due to the uniqueness of their flora and fauna, presence of endemic species and/or provided ecosystem services (Tibbett 2015). Due to the soil porosity and permeability in these formations, they have high water recharge capacity and storage, forming large aquifers that supply springs and cities (Carmo et al. 2012). However, because they are located in regions with large mineral deposits of economic interest, they are among the most endangered landscapes in the world (Jacobi & Carmo 2008a, Tibbett 2015).

These environments, originated in the Archean and Paleoproterozoic period, are usually located in mountain tops, but can also be found in foothills (Souza & Carmo 2015). In addition to presenting high biological value, these environments harbor sites of inestimable archaeological value and important water resource deposits (Jacobi et al. 2015, Souza & Carmo 2015). In Brazil, ferruginous geosystems occur in the states of Bahia, Minas Gerais, Mato Grosso do Sul and Pará, and they are important mineral exploration areas (Carmo et al. 2012). These geosystems, known in Brazil as “cangas”, usually occur in higher relief areas, with tabular tops (Souza & Carmo 2015). However, in the Urucum Plateau region, located in the municipalities of Corumbá and Ladário, state of Mato Grosso do Sul, they not only occur on tops but also in low altimetric levels and slopes (Del’arco et al. 1982, Takahasi 2015). These low altimetric ironstone outcrops are called “bancadas lateríticas” (Takahasi & Meirelles 2014).

The Urucum Plateau represents the lithostratigraphic unit of most economic interest in Mato Grosso do Sul, due to the presence of important deposits of iron and manganese (Del’arco et al. 1982). Ironstone outcrops of Urucum plateau are Quaternary deposit formations produced under climatic conditions different from those of the current era. They probably occurred at the time of the Paraguay River Depression and the plio-plestocene plediplain origin, period in which a semi-arid weather subjected to torrential rains and erosive processes prevailed (Del’arco et al. 1982).

In Brazil, the knowledge about floristic and ecology of plant communities associated with ferruginous geosystems is still incipient (Jacobi & Carmo 2011, Jacobi et al. 2015). These habitats are among the most threatened and least studied in Brazil respectively due to their association with iron ore deposits with high quality and the difficulty of access (Jacobi & Carmo 2008a). Studies on ironstone outcrops flora are recent and concentrated largely on the Iron Quadrangle, in the state of Minas Gerais (Mourão & Stehmann 2007, Viana & Lombardi 2007, Pifano et al. 2010, Ataíde et al. 2011, Carmo & Jacobi 2013). The results obtained by those studies indicate that ironstone outcrops harbor a large number of plant species, contributing to the increase of the alpha diversity of the regions where they occur (Jacobi & Carmo 2008a).

In the region of Corumbá, some ironstone outcrops in the Urucum plateau have been studied for their ecological aspects (Takahasi 2010, Takahasi & Meirelles 2014, Oliveira 2016) and flora (Takahasi 2010, Takahasi 2015); but there is no listing that includes all species already collected in the region. In this study we present a checklist of species of Angiosperms from the ironstone outcrops in Urucum Plateau, based on several collecting efforts carried out in region from the 1990s to the present time, in order to fill the information gaps about the flora of these environments and evaluate the similarity between the ferruginous outcrops from Mato Grosso do Sul and those ferruginous outcrops from other regions.

Material and Methods

The studied ironstone outcrops are located at the foot of the Urucum Plateau Residual, a non-floodable region around the municipalities of Corumbá and Ladário (Figure 1), the western border of Pantanal, Mato Grosso do Sul, Midwest region of Brazil. The plateau, also known as Urucum Massif, is a complex of hills called locally as Ururum, Santa Cruz, Grande, Rabichão, São Domingos and Tromba dos Macacos, whose altitudes vary between 80 to 1.065 m, being the highest hill recognized as the highest point of the State (Borges et al. 1997, Damasceno-Junior 2005). The area covers approximately 1.211 km² and is bordered on north by the Paraguay River, on west by the Bolivian border, on south and east by the Pantanal floodplain (Silva et al. 2000). Ironstone outcrops from this region occur along the drainage lines at the foot of the plateau hills (about 100 to 150 m altitude), and due to the predominantly flat terrain, small pools of water may accumulate during the rainy season.

Ten ironstone outcrops were included in this inventory: Pantanal Park Road, Band’alta farm, Monjolinho farm, Figueira farm, São João farm, São Sebastião do Carandá farm, two sites in the Municipal Natural Park Piraputangas, Uruba farm and Rabicho farm (Table 1).

In the Urucum Plateau region, the average annual temperature is 25.1 ºC and the average rainfall is 1.070 mm annually (Soriano 1997). There are two well-defined seasons, a dry season that runs from May to September and a rainy season from October to March, with 45% of rainfall occurring from December to February (Loureiro et al. 1982).

The vegetation surrounding these ironstone outcrops is a Submontane Seasonal Decidual Forest (Damasceno-Junior 2005). We can characterize three habitats in ironstone outcrops at Urucum Plateau: the first one is hardened ferruginous substrate where plants established directly on them or in places with a thin layer of sediment. The second one consists of soil islands, specially mats of monocotyledons, with a deeper layer of soil that allows establishment of phanerophytes. Finally, the third one is constituted by ephemeral flush communities that occurs on runoff-habitats like the slopes of ironstone outcrops allowing the establishment of typical flooded plant species.

The checklist of the ironstone outcrops flora in the Urucum Plateau was elaborated through data collected in Fazenda Band’alta, from January 2017 to July 2018; in researches made by the authors over several years in the outcrops from the region and Herbaria queries at Universidade Federal de Mato Grosso do Sul, Campus Corumbá (COR) and Campo Grande (CGMS); Herbarium of Embrapa Pantanal (CPAP); Herbarium Friburguense of Pontifícia Universidade Católica do Rio de Janeiro (FCAB); Herbarium of Universidade Estadual de Campinas (UEC); Herbarium of Instituto de Biociências at Universidade do Rio Grande do Sul (ICN); Herbarium Maria Eneyda P. K. Fidalgo, at Instituto de Botânica de São Paulo (SP) and Herbarium of Universidade de Brasília (UB). The obtained dataset covers a large part of the ironstone outcrops flora in the region, and was later supplemented with herbaria data available on internet (CRIA 2018, Flora do Brasil 2020,

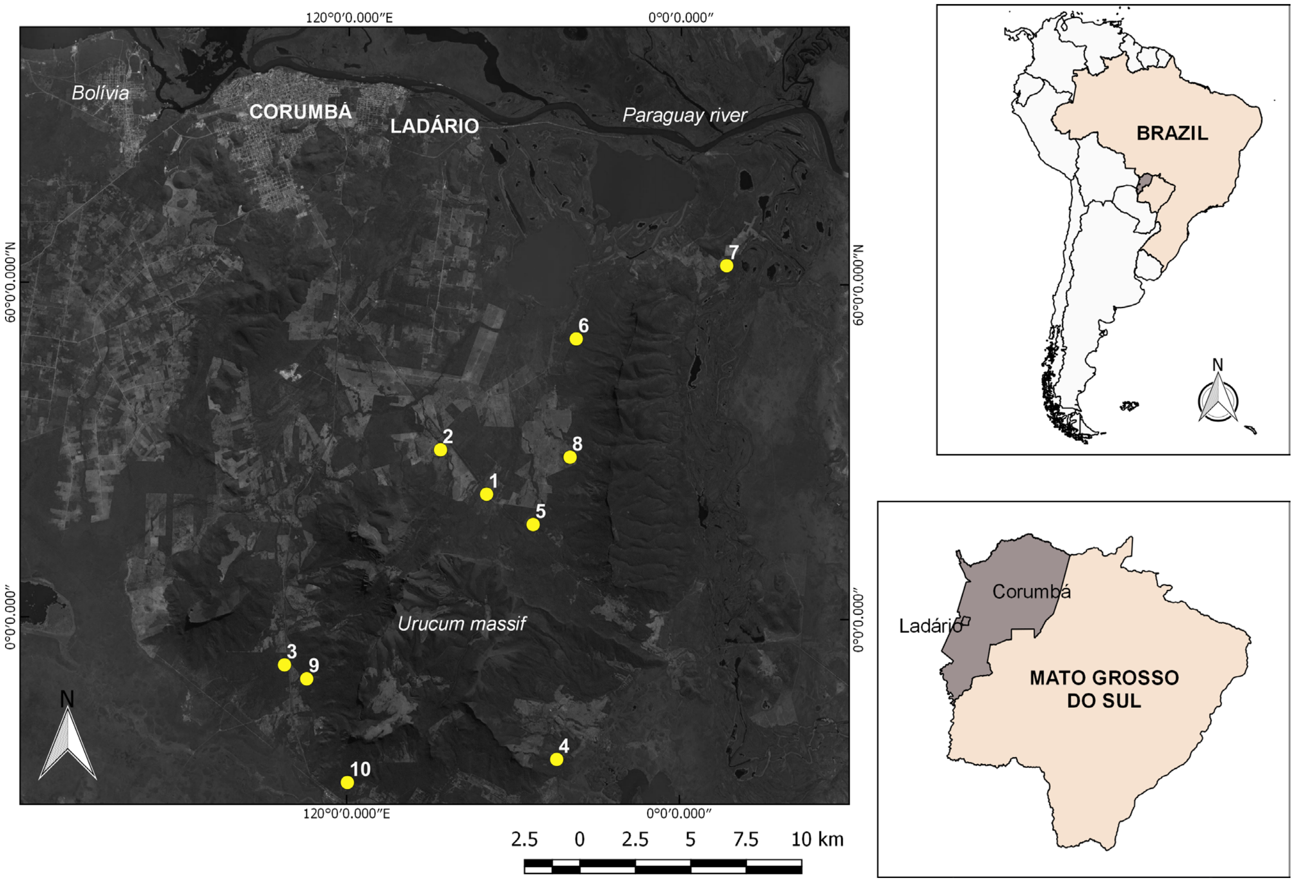

Figure 1. Location of the ten analyzed cangas (yellow dots) at the Urucum Plateau, Western Border of Pantanal, MS.

Table 1. Locations included in this study with their respective geographical coordinates.

Sampling points	Locality	Geographical coordinates
1	Pantanal Park Road	19° 10'02.0"S, 57° 33'31.0"W
2	Band'Alta farm	19° 08'57.3"S, 57° 34'42.1"W
3	Figueira farm	19° 14'10.7"S, 57° 38'43.1"W
4	Monjolinho farm	19° 16'28.4"S, 57° 31'42.7"W
5	São João farm	19° 10'46.2"S, 57° 32'19.1"W
6	São Sebastião do Carandá farm	19° 06'15.5"S, 57° 31'12.5"W
7	Uruba farm	19° 04'28.8"S, 57° 27'20.2"W
8	Rabicho farm	19° 09'08.0"S, 57° 31'22.0"W
9	Municipal Natural Park Piraputangas	19° 14'31.0"S, 57° 38'08.0"W
10	Municipal Natural Park Piraputangas	19° 17'02.0"S, 57° 37'06.0"W

Jabot 2018). We considered only specimens identified at the taxonomic level of species and excluded those with dubious identification or at the genera-level. The taxa classification followed the APG IV system (2016), and the nomenclature and synonymizations were updated according to Flora do Brasil 2020 (2018). The similarity in species composition among the 10 analyzed ironstone outcrops was calculated using the Sorensen Similarity Index.

Results

A total of 302 species distributed in 53 botanical families and 175 genera were cataloged (Table 2). The richest species families were Poaceae (43 species), Fabaceae (41), Euphorbiaceae (22), Malvaceae (19), Cyperaceae (19), Convolvulaceae (15), Malpighiaceae (13) and Apocynaceae (11) that represented 60.6% of the specific richness found in the ironstone outcropsof the region (Figure 2). Poaceae, Fabaceae, Euphorbiaceae and Malvaceae are also the families with the highest number of genera, being *Cyperus* (9), *Croton* (8), *Mimosa* (7), *Portulaca* (7) and *Evolvulus* (6) the most common genera.

In the soil islands, there are deciduous forest species as *Aspidosperma quirandy* Hassl., *Pseudobombax marginatum* (A.St.-Hil.) A.Robyns and *Myracrodruon urundeuva* Allemão, whereas in areas where there is a thin layer of soil only herbaceous species can be established, in many cases annuals for example, *Gomphrena centrota*

Table 2. List of Angiosperms species from the cangas at the Urucum Plateau, Western Border of Pantanal, MS, with respective growth habits, Vouchers (collector's name, collection number and registration in the herbarium where the specimen is deposited, when possible), place of occurrence and state of conservation of the species according to criteria of the International Union of Conservation and Natural Resources (IUCN 2018) and Livro Vermelho da Flora do Brasil pela CNCFlora (Martinelli & Moraes 2013): CR = critically endangered , EN = endangered, LC = least concern , NT = near threatened, VU = vulnerable, DD = data deficient, "─" = not evaluted. The numbers of localities are shown in Table 1.

Species	Growth habit	Vouchers	Locality	Conservation status
Acanthaceae				
Justicia cf. *harleyi* Wassh.	Shrub	Damasceno-Jr,G.A. 1517 (COR 6090)	1	-
Ruellia ciliatiflora Hook.	Herb	Takahasi, A. 1032	4	-
Ruellia erythropus (Nees) Lindau	Herb	Damasceno-Jr,G.A. 1511 (COR 6085)	1	-
Stenandrium pohllii Nees.	Herb	Takahasi, A.818	4	-
Thyrsacanthus boliviensis (Nees) A.Côrtes&Rapini	Shrub	Takahasi, A. 1396 (COR 15350)	1	-
Amaranthaceae				
Alternanthera flavescens Kunth	Herb	Damasceno-Jr,G.A. 1310 (FCAB 5921)	1	-
Alternanthera pungens Kunth	Herb	Damasceno-Jr,G.A. 1504 (COR 6007)	1	-
Alternanthera rufa (Mart.) D.Dietr.	Shrub	Damasceno-Jr,G.A. 1159 (COR 13039)	2	-
Alternanthera tenella Colla	Herb	Damasceno-Jr,G.A. 1492 (COR 6008)	1	-
Gomphrena celosioides Mart.	Herb	Silva, R.H. 964 (CGMS 38691); Takahasi, A. 745; Takahasi, A. 938 (COR 15113)	1, 3, 4	-
Gomphrena centrota E. Holzh.	Herb	Pott, V.J. 7408 (CGMS 36403); Damasceno-Jr,G.A. 1113 (COR 13043); Takahasi, A. 971 (COR 15136); Takahasi, A. 1040 (COR 15170)	1, 2, 3, 5	EN (CNNFlora)
Gomphrena matogrossensis Suess.	Herb	Damasceno-Jr,G.A. 1335 (COR 13504)	1	-
Gomphrena vaga Mart.	Shrub	Takahasi, A. 701 (COR 14995); Takahasi, A. 1097 (COR 15193); Takahasi, A. 1051 (COR 15175)	1, 2, 3	-
Amaryllidaceae				
Zephyranthes cearensis (Herb.) Baker	Herb	Takahasi, A. 782 (COR 15031); Takahasi, A. 947 (COR 15119)	2, 4	-
Anacardiaceae				
Myracrodruon urundeuva Allemão	Tree	Lima, M.S. 276	2	-
Annonaceae				
Annona nutans (R.E. Fr.) R.E. Fr.	Shrub	Takahasi, A. 964 (COR 15130); Takahasi, A. 991 (COR 15145); Damasceno-Jr,G.A. 2459 (COR 11089); Silva, R.H. 911 (CGMS 38696)	3, 4, 7, 10	-
Apocynaceae				
Araujia stuckertiana (Kurtz ex Heger) Fontella & Goyder	Liana	Damasceno-Jr,G.A. 1514 (COR 6082)	1	-
Aspidosperma cuspa (Kunth) S.F.Blake ex Pittier	Tree	Takahasi, A. 1408	6	-
Aspidosperma pyrifolium Mart.	Tree	Damasceno-Jr,G.A. 5317 (CGMS 41015); Takahasi, A. 721 (COR 15006); Takahasi, A. 1120 (COR 15205)		
	1, 2, 4	-		
Aspidosperma quirandy Hassl.	Tree	Damasceno-Jr,G.A. 1338 (COR 9197); Takahasi,A. 1449; Takahasi, A. 698 (COR 14994); Pott, A. 9285 (CGMS 58890)	1, 4, 5, 7	-
Aspidosperma subincanum Mart. ex A.DC.	Tree	Damasceno-Jr, G.A. 1174		

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
	2	-		
Blepharodon pictum (Vahl) W.D. Stevens	Liana	Dasmasceno 1469 (COR 10924); Takahasi, A. 1177 (COR 15232); Takahasi, A. 1094 (COR 15191); Silva, R.H. 878 (CGMS 38698)	1, 2, 4, 8	-
Forsteronia cf. *pubescens* A. DC.	Liana	André, C.B.D.S. 201 (COR 15817)	9	-
Forsteronia thyrsoidea (Vell.) Müll. Arg.	Liana	Takahasi, A. 1445	6	-
Petalostelma robertii (S. Moore) Liede & Meve	Liana	Takahasi, A. 1317 (COR 15302); Silva, R.H. 909 (CGMS 38697)	6, 8	-
Prestonia tomentosa R.Br.	Liana	Takahasi, A. 1410	6	-
Schubertia grandiflora Mart.	Liana	Damasceno-Jr,G.A. 1386 (COR 9202)	1	-
Arecaceae				
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	Palm	Lima, M.S. 280	2	-
Asteraceae				
Calea rupicola Chodat	Herb	Damasceno-Jr,G.A. 1301 (COR 13499); Damasceno-Jr,G.A. 1116 (COR 13038); Takahasi, A.712; Takahasi, A. 1089 (COR 15187); Takahasi, A. 1039 (COR 15169) Silva, R.H. 880 (CGMS 38704)	1, 2, 3, 4, 5, 8	-
Conyza bonariensis (L.) Cronquist	Herb	Takahasi, A. 978	3	-
Lepidaploa amambaia H.Rob.	Herb	Damasceno-Jr,G.A. 1307 (COR 13498)	1	-
Lepidaploa remotiflora (Rich.) H. Rob.	Herb	Damasceno-Jr,G.A. 1502 (COR 6004); Takahasi, A.974 (COR 12648)	1, 3	-
Lepidaploa salzmannii (DC) H.Rob.	Herb	Takahasi, A. 702; Urquiza, M.V.S. 110 (COR 15860); Takahasi, A. 936 (COR 15111)	1, 2, 4	-
Bignoniaceae				
Dolichandra quadrivalvis (Jacq.) L.G.Lohmann	Liana	Pott, A. 12707 (CGMS 58779)	1	-
Fridericia triplinervia (Mart. ex DC.) L.G. Lohmann	Liana	Damasceno-Jr,G.A. 1414 (COR 9204); Damasceno-Jr,G.A. 1201 (COR 13678)	1, 2	-
Handroanthus impetiginosus (Mart. ex DC.) Mattos	Tree	Lima, M.S. 281	2	NT (CNNFlora)
Jacaranda cuspidifolia Mart.	Tree	Takahasi, A. 1121 (COR 15371)	4	-
Bixaceae				
Cochlospermum regium (Schrank) Pilg.	Shrub	Takahasi, A. 705 (COR 14997); Damasceno-Jr,G.A. 1676 (COR 13148); Takahasi, A. 718 (COR 15004); Pott, A. 9300 (CGMS 52018); André, C.B.D.S. 20 (COR 15824)	1, 2, 3, 7, 9	-
Boraginaceae				
Euploca procumbens (Mill.) Diane & Hilger	Herb	Takahasi, A. 945 (COR 15363)	4	-
Brassicaceae				
Capparidastrum cf. *humile* (Hassl.) Cornejo & Iltis	Shrub	Damasceno-Jr,G.A. 1343 (COR 13500)	1	-
Bromeliaceae				
Bromelia balansae Mez	Succulent	Lima, M.S. 279	2	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Deuterocohnia meziana Kuntze ex Mez	Succulent	Damasceno-Jr, G.A. 5316 (CGMS 41014); Takahasi, A. 722 (COR 15007); Takahasi, A. 751	1, 2, 3	VU (CNNFlora)
Dyckia aff. *gracilis* Mez	Succulent	Damasceno-Jr,G.A. 1404 (COR 10917); Ishii, I.H. 743 (COR 13576)	1, 5	-
Dyckia excelsa Leme	Succulent	Takahasi, A. 1098 (COR 15367)	5	-
Dyckia leptostachya Baker	Succulent	Ishii 746 (COR 15872); Ishii, I.H. 747 (COR 15389); Ishii, I.H.786 (COR 15730)	1, 2, 5	-
Tillandsia loliacea Mart. ex Schult & Schult f.	Epiphyte	Takahasi, A. 1091	4	-
Burseraceae				
Commiphora leptophloeos (Mart.) J.B. Gillett	Tree	Damasceno-Jr, G.A.1329; Lima, M.S. 257; Takahasi, A. 1122 (COR 15206); Takahasi, A. 729; Damasceno-Jr, G.A. 2792	1, 2, 4, 5, 6	-
Cactaceae				
Cereus bicolor Rizzini & A.Mattos	Succulent	Takahasi, A. 1376 (COR 15342)	4	LC (IUCN)
Discocactus ferricola Buining & Brederoo	Succulent	Garcia, J.S. 55 (CGMS17537),		
	1, 2, 3	EN (IUCN), DD (CNNFlora)		
Frailea cataphracta (Dams) Britton & Rose	Succulent	Takahasi, A. 779 (COR 15028)	2	NT (IUCN)
Harrisia balansae (K. Schum.) N.P. Taylor & Zappi	Succulent	Takahasi, A. 755 (COR 15017)	2	LC (IUCN)
Opuntia retrorsa Speg.	Succulent	Takahasi, A. 672 (COR 14895); Lima, M.S. 282	1, 2	-
Praecereus euchlorus (F.A.C. Weber ex K. Schum.) N.P. Taylor	Succulent	Damasceno-Jr,G.A. 1354 (COR 13501); Takahasi, A.1096; Takahasi, A.1171; Damasceno-Jr, G.A. 2805A	1, 2, 4, 6	LC (IUCN)
Cannabaceae				
Celtis iguanaea (Jacq.) Sarg.	Shrub	Takahasi, A. 1461 (COR 15355); Takahasi, A. 1346 (COR 15317); Silva, R.H 915 (CGMS 38725)	3, 4, 9	-
Caryophyllaceae				
Polycarpaea corymbosa (L.) Lam.	Herb	Takahasi, A. 680 (COR 14990); Takahasi, A. 973 (COR 15138); Takahasi, A.875; Silva, R.H. 899 (CGMS 38728)	1, 3, 5, 8	-
Cleomaceae				
Physostemon guianense (Aubl.) Malme	Herb	Damasceno-Jr,G.A. 1434 (COR 13866); Damasceno-Jr,G.A. 1677 (COR 13676); Takahasi, A. 815 (COR 15051); Pott, A. 4784 (CPAP 25125)	1, 2, 4, 7	-
Tarenaya eosina (J.F.Macbr.) Soares Neto & Roalson	Herb	Damasceno-Jr,G.A. 1312 (COR 13865); Takahasi, A. 1002 (COR 15150); Takahasi, A. 915 (COR 15100); Silva, R.H. 882 (CGMS 38729)	1, 2, 3, 8	-
Combretaceae				
Combretum duarteanum Cambess.	Shrub	Damasceno-Jr,G.A. 1304 (COR 13864); Damasceno-Jr,G.A. 1155 (COR 13618); Takahasi, A. 825 (COR 15059)	1, 2, 4	-
Combretum leprosum Mart.	Tree	Takahasi, A. 766 (COR 15021)	2	-
Combretum mellifluum Eichler	Tree	Pott, A. 9271 (CPAP 22949)	7	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Terminalia argentea Mart.	Tree	Takahasi, A. 1044; Silva, R.H. 941 (CGMS 38733)	4, 9	-
Commelinaceae				
Commelina benghalensis L.	Herb	Damasceno-Jr,G.A. 1424 (COR 13517); Takahasi, A. 1005 (COR 15152)	1, 2	LC (IUCN)
Commelina erecta L.	Herb	Damasceno-Jr,G.A. 1418 (COR 10894); Takahasi, A. 1004; Takahasi, A.732	1, 2, 3	LC (IUCN)
Commelina platyphylla Klotzsch ex Seub.	Herb	Takahasi, A. 1133 (COR 15212)	3	-
Tradescantia boliviana (Hassk.) J.R.Grant	Herb	Takahasi, A. 1175 (COR 15230)	2	-
Tripogandra glandulosa (Seub.) Rohweder	Herb	Takahasi, A. 1186 (COR 15236); Damasceno-Jr,G.A. 2881 (COR 5926); Silva, R.H. 905 (CGMS 38734)	2, 6, 8	-
Convolvulaceae				
Bonamia agrostopolis (Vell.) Hallier f.	Liana	Damasceno-Jr,G.A. 1300 (COR 9189)	1	-
Bonamia balansae Hallier f.	Liana	Damasceno-Jr,G.A. 1350 (COR 13628)	1	-
Bonamia subsessilis Hassl.	Liana	Damasceno-Jr, G.A. 2880A (COR 5927)	6	-
Evolvulus alopecuroides Mart.	Herb	Takahasi, A. 1000 (COR 15149); Takahasi, A. 954 (COR 15122); Silva, R.H. 910 (CGMS 38738)	2, 6, 10	-
Evolvulus cf. *chamaepitys* Mart.	Herb	Silva, R.H. 935 (CGMS 38739)	9	-
Evolvulus cf. *chrysotrichos* Meisn.	Herb	Damasceno-Jr,G.A. 1491 (COR 13860); Damasceno-Jr,G.A. 1680 (COR 13612)	1, 2	EN (CNNFlora)
Evolvulus filipes Mart.	Herb	Takahasi, A. 992 (COR 15146)	4	-
Evolvulus glomeratus Nees & C. Mart.	Herb	Takahasi, A. 1083 (COR 15182)	3	-
Evolvulus lithospermoides Mart.	Herb	Damasceno-Jr,G.A. 1332 (COR 13861); Takahasi, A. 1295 (COR 15283); Takahasi, A. 791 (COR 15038)	1, 2, 3	-
Ipomoea cf. *hieronymi* (Kuntze) O'Donell	Liana	Silva, R.H. 876 (CGMS 38737)	1	-
Ipomoea nil (L.) Roth	Liana	Takahasi, A. 1393 (COR 15348)	2	-
Ipomoea sericophylla Meisn.	Liana	Takahasi, A. 833 (COR 15359); Takahasi, A. 895 (COR 15091)	2, 3	-
Jacquemontia evolvuloides Meisn.	Liana	Damasceno-Jr,G.A. Jr 1423 (COR 13886); Takahasi, A. 763 (COR 15020)	1, 2	-
Jacquemontia fruticulosa Hallier f.	Liana	Takahasi, A. 940 (COR 15115)	4	-
Jacquemontia heterantha (Nees & Mart.) Hallier f.	Liana	Takahasi, A. 708 (UEC 192869); Takahasi, A.1296 (COR 15284)	1, 2	-
Cyperaceae				
Bulbostylis brevifolia Palla	Herb	Takahasi, A. 1030 (COR 12546)	3	-
Bulbostylis conifera (Kunth) C.B.Clarke	Herb	Takahasi, A. 884 (COR 12544)	5	-
Cyperus aff. *meyenianus* Kunth	Herb	Damasceno-Jr,G.A. 1308A (COR 13858)	1	-
Cyperus aggregatus (Willd.) Endl.	Herb	Damasceno-Jr,G.A. Jr 1428 (COR 13714); Takahasi, A. 1010 (COR 12545); Takahasi, A. 905; Takahasi, A. 1275 (COR 12553)	1, 2, 3, 4	-
Cyperus cornelii-ostenii Kük.	Herb	Silva, R.H. 959 (CGMS 38743); Takahasi, A. 1378 (COR 12564); Takahasi, A. 1155 (COR 12548); Takahasi, A. 827 (COR 15060); Takahasi, A. 877 (COR 12543)	1, 2, 3, 4, 5	-
Cyperus cuspidatus Kunth	Herb	Damasceno-Jr,G.A. 1415 (COR 13715); Damasceno-Jr,G.A. 1685 (COR 15914)	1, 2	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Cyperus flavescens L.	Herb	Silva, R.H. 940 (CGMS 38751)	9	-
Cyperus laxus Lam.	Herb	Takahasi, A. 1377 (COR 12563); Takahasi, A. 1263 (COR 12551)	3, 4	-
Cyperus subcastaneus D.A. Simpson	Herb	Takahasi, A. 1379 (COR 12565)	6	-
Cyperus surinamensis Rottb.	Herb	Takahasi, A. 868 (COR 15075); Takahasi, A. 793 (COR 12560)	2, 3	-
Cyperus uncinulatus Schrad. ex Nees	Herb	Takahasi, A. 1129 (COR 12547); Takahasi, A. 835 (COR 15064); Takahasi, A. 880 (COR 15082)	2, 4, 5	-
Eleocharis contracta Maury ex Micheli	Herb	Damasceno-Jr,G.A. 2412 (COR 11069)	1	-
Eleocharis nigrescens (Nees) Kunth	Herb	Takahasi, A. 1239 (COR 12559)	2	-
Eleocharis rugosa D.A.Simpson	Herb	Takahasi, A. 1243 (COR 12550)	2	-
Fimbristylis complanata (Retz.) Link	Herb	Silva, R.H 962 (CGMS 38745)	1	LC (IUCN)
Fimbristylis cf. *dichotoma* (L.) Vahl	Herb	Takahasi, A. 1338 (ICN 156812)	2	LC (IUCN)
Fimbristylis miliacea (L.) Vahl	Herb	Damasceno-Jr, G.A. 2413A	1	-
Kyllinga odorata Vahl	Herb	Takahasi, A. 1182 (COR 15234); Takahasi, A. 1268 (ICN 156813)	2, 4	-
Rhynchospora contracta (Nees) J.Raynal	Herb	Damasceno-Jr, G.A. 2413 (COR 15913); Takahasi, A. 1228 (COR 15256)	1, 2	-
Dioscoreaceae				
Dioscorea acanthogene Rusby	Liana	Damasceno-Jr, G.A. 2880 (11122)	6	-
Dioscorea trifida L.f.	Liana	Silva, R.H. 944 (CGMS 38753)	4	-
Erythroxylaceae				
Erythroxylum deciduum A. St.-Hil.	Shrub	Takahasi, A. 1316 (COR 15301)	6	-
Euphorbiaceae				
Acalypha brasiliensis Müll.Arg.	Shrub	Silva, R.H. 928 (CGMS 38772)	10	-
Acalypha communis Müll. Arg.	Shrub	Takahasi, A. 1235 (COR 15260) Takahasi, A. 1025 (COR 15162) Takahasi, A. 822 (COR 15058)	2, 3, 4	-
Acalypha villosa Jacq.	Shrub	Takahasi, A. 949 (COR 12389)	4	-
Actinostemon klotzschii (Didr.) Pax	Shrub	Takahasi, A. 741 (12395); Takahasi, A. 1119 COR 12392)	3, 6	-
Astraea lobata (L.) Klotzch	Herb	Takahasi, A. 832 COR 12384)	3	-
Cnidoscolus urens (L.) Arthur	Shrub	Takahasi, A. 1304 (COR 15291)	2	-
Cnidoscolus vitifolius var. *cnicodendrum* (Griseb.) Lourteig & O'Donnell	Tree	Damasceno-Jr,G.A. 1397 (COR 13885)	1	-
Croton antisyphiliticus Mart.	Shrub	Takahasi, A. 929 (15107)	3	-
Croton campestris A. St. Hill	Shrub	André, C.B.D.S 12 (COR 15836)	9	-
Croton corumbensis S.Moore	Shrub	Takahasi, A. 801	9	-
Croton didrichsenii G.L.Webster	Shrub	Takahasi, A. 801 (COR 12382)	3	-
Croton glandulosus L.	Herb	Takahasi, A. 1320 (COR 15304)	2	-
Croton pedicellatus Kunth	Herb	Takahasi, A. 1246 (COR 15264)	4	-
Croton sarcopetaloides S.Moore	Shrub	Silva, R.H. 931 (CGMS 38773)	9	-
Croton triqueter Lam.	Shrub	Takahasi, A. 892 (COR 12385)	3	-
Dalechampia brasiliensis Lam.	Liana	Takahasi, A. 1247 (COR 15265)	4	-
Euphorbia thymifolia L.	Herb	Takahasi,A. 1370 (COR 15336)	4	-

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Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Jatropha ribifolia (Pohl) Baill.	Shrub	Takahasi, A. 706 (COR 14998); Takahasi, A. 759(COR 15018); Takahasi, A. 710 (COR 15001)	1, 2, 3	-
Jatropha weddeliana Baill.	Shrub	Damasceno-Jr,G.A. Jr 1316 (COR 13883)	1	-
Manihot anomala Pohl	Shrub	Takahasi, A. 806 (COR 12383); Silva, R.H. 919 (CGMS 38771)	3, 10	-
Manihot guaranitica Chodat & Hassl.	Shrub	Takahasi, A. 767 (COR 15022)	2	-
Microstachys hispida (Mart.) Govaerts	Herb	Takahasi, A. 1028 (COR 15165); Silva, R.H. 937 (CGMS 38774)	3, 9	-
Fabaceae				
Aeschynomene histrix Poir.	Shrub	Damasceno-Jr,G.A. 1318; Takahasi, A. 997 (COR 15148); Takahasi, A. 821 (COR 15057); Takahasi, A. 955 (COR 15123); Pott, V.J. 4781 (CGMS 53934); Silva, R.H. 877 (CGMS 38777)	1, 3, 4, 6, 7, 8	-
Alysicarpus vaginalis (L.) DC.	Herb	Takahasi, A. 1019 (COR 15159)	2	-
Amburana cearensis (Allemão) A.C. Sm.	Tree	Lima, M.S. 283; Damasceno-Jr, G.A. 2882; Silva, R.R 864 (COR 14763)	2, 6, 7	EN (IUCN), NT (CNNFlora)
Anadenanthera colubrina (Vell.) Brenan	Tree	Lima, M.S. 277	2	-
Bauhinia leptantha Malme	Shrub	Silva, R.R 462 (UEC 141018)	7	VU (CNNFlora)
Bauhinia pentandra (Bong.) Vogel ex Steud.	Shrub	Damasceno-Jr,G.A. 1303 (COR 11173); Takahasi, A. 961 (COR 15128); Silva, R.R. 634 (UEC 141026); Silva, R.H. 913 (CGMS 38796)	1, 3, 7, 10	-
Camptosema ellipticum (Desv.) Burkart	Liana	Takahasi, A. 1041 (COR 15171); Takahasi, A. 1093 (COR 15190); Takahasi, A. 1435	2, 4, 6	-
Canavalia brasiliensis Benth.	Liana	Takahasi, A. 1374 (COR 15340)	2	-
Centrosema pascuorum Benth.	Liana	Takahasi, A. 1373 (COR 15339)	2	-
Chamaecrista flexuosa (L.) Greene	Shrub	Damasceno-Jr,G.A. 1431 (COR 13878); Takahasi, A. 1107 (COR 15197); Silva, R.R 544 (UEC 140836); Silva, R.H 881 (CGMS 38778); Souza, N. 8 (COR 15792)	1, 6, 7, 8, 9	-
Chamaecrista nictitans (L.) Moench	Shrub	Takahasi, A. 960 (COR 15127); André, C.B.D.S. 81 (COR 15840)	3, 9	LC (IUCN)
Chamaecrista serpens (L.)Greene	Shrub	Damasceno-Jr,G.A. 1302 (COR 12616); Takahasi, A. 1006 (COR 15153); Silva, R.R 546 (COR 14633); Silva, R.H. 930 (CGMS 38798)	1, 2, 7, 9	-
Chamaecrista supplex (Benth.) Britton & Killip	Herb	Takahasi, A. 885 (COR 15084)	5	-
Crotalaria pallida Aiton	Shrub	Damasceno-Jr,G.A. 2409 (COR 6462)	1	-
Dipteryx alata Vogel	Tree	Takahasi, A. 1319 (COR 15303); Takahasi, A. 684 (COR 14992); Almeida, L.W. 18 (COR 16107)	2, 5, 9	VU (IUCN)
Guibourtia hymenaefolia (Moric.) J. Léonard	Tree	Damasceno-Jr,G.A. 1340 (COR13881); Takahasi, A. 1314 (COR 15299)	1, 6	-
Hymenaea stigonocarpa Hayne	Tree	Almeida, L.W. 17 (COR 16106)	9	-
Macroptilium bracteatum (Nees & C.Mart.) Marechal & Bau	Shrub	Takahasi, A. 996 (COR 15147)	3	LC (IUCN)
Macroptilium lathyroides (L.) Urb.	Liana	Takahasi, A. 1372 (COR 15338)	2	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Mimosa bimucronata (DC.) Kuntze	Shrub	Silva, R.H. 965 (CGMS 38784); Takahasi, A. 1009 (COR 15154)	1, 2	LC (IUCN)
Mimosa candollei R.Grether	Shrub	Silva, R.R 339 (COR 14654)	7	-
Mimosa craspedisetosa Fortunato & Palese	Shrub	Silva, R.R 750 (UEC 143340)	7	-
Mimosa debilis Humb. & Bonpl. ex Willd. var. debilis	Herb	Lima, M.S. 284; Takahasi, A. 803 (COR 15043); Takahasi, A. 1140 (COR 15217); Silva, R.R 1339 (COR 14798); Silva, R.H 894 (CGMS 38780)	2, 3, 6, 7, 8	LC (IUCN)
Mimosa polycarpa Kunth	Shrub	Silva, R.R. 874 (UEC 142402)	7	-
Mimosa sensibilis var. *urucumensis* Barneby	Shrub	Takahasi, A. 1080 (COR 15179); Takahasi, A. 1087 (COR 15186); Silva, R.R 1096 (COR 14687)	3, 4, 7	-
Mimosa xanthocentra Mart.	Shrub	Takahasi, A. 1020 (COR 15160); Takahasi, A. 921 (COR 15104); Takahasi, A. 1092 (COR 15189); Takahasi, A. 958 (COR 15125); Silva, R.R. 646 (UEC 140958)	2, 3, 4, 6, 7	LC (IUCN)
Muellera variabilis (RR.Silva & AMG. Azevedo) MJ.Silva & AMG.Azevedo	Tree	Takahasi, A. 726 (COR 15010); Takahasi, A. 1137 (COR 15215)	2, 3	-
Senegalia cf. *martii* (Benth.) Seigler & Ebinger	Shrub	Damasceno-Jr,G.A. 1342 (COR 13709)	1	-
Senegalia polyphylla (DC.) Britton & Rose	Tree	Damasceno-Jr,G.A. 1346 (COR 13708)	1	-
Senegalia cf. *riparia* (Kunth) Britton & Rose ex Britton & Killip	Shrub	Damasceno-Jr,G.A. 1341 (COR 13711)	1	LC (IUCN)
Senegalia tenuifolia (L.) Britton & Rose	Shrub	Damasceno-Jr,G.A. 1351 (COR 13706); Takahasi, A, 1112 (COR 15200)	1, 2	-
Senna obtusifolia (L.) H.S.Irwin & Barneby	Shrub	Silva, R.H. 901 (CGMS 38781)	8	-
Senna occidentalis (L.) Link	Shrub	Damasceno-Jr, G.A. 1177	2	-
Senna pilifera (Vogel) H.S. Irwin & Barneby	Shrub	Takahasi, A. 707; Takahasi, A. 831 (COR 15062); Takahasi, A. 927 (COR 15106); Takahasi,A. 841 (COR 15066); Silva, R.H. 924 (CGMS 38797)	1, 2, 3, 4, 10	-
Stylosanthes acuminata M.B.Ferreira & Sousa Costa	Herb	Takahasi, A. 795 (COR 15040); Takahasi, A. 844 (15067); Takahasi, A. 956 (COR 15124); Souza, N. 10 (COR 15808)	3, 4, 6, 9	-
Stylosanthes capitata Vogel	Herb	Takahasi, A. 1108 (COR 15158)	6	-
Stylosanthes guianensis (Aubl.) Sw.	Herb	Silva, R.R. 405 (UEC 141003)	7	-
Stylosanthes montevidensis Vogel	Herb	Damasceno-Jr, G.A. 1319 (UEC 140180)	1	-
Zornia cf. *crinita* (Mohlenbr.) Vanni	Herb	Damasceno-Jr, G.A. 4785 (CGMS 52405)	1	-
Zornia latifolia Sm.	Herb	Silva, R.R 364 (COR 14650)	7	-
Zornia reticulata Sm.	Herb	Culau, R. 16 (UEC 140174); Takahasi, A. 802 (COR 15042); Silva, R.R 549 (COR 14651); Silva, R.H. 908 (CGMS 38782)	1, 3, 7, 8	-
Iridaceae				
Cipura formosa Ravenna	Herb	Silva, R.H. 949 (CGMS 38805); Takahasi, A. 1181 (COR 15233); Takahasi, A. 1261	1, 2, 4	-
Krameriaceae				
Krameria grandiflora A. St. Hill	Herb	Takahasi, A. 784; Takahasi, A. 808; Pott, V.J. 4780 (CGMS 52708); Almeida, F.L.R. 38 (COR 15848)	2, 3, 7, 9	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Lamiaceae				
Hyptis brevipes Poit.	Herb	Takahasi, A. 1012 (COR 15156); Takahasi, A. 966	2, 3	-
Mesosphaerum pectinatum (L.) Kuntze	Herb	Takahasi, A. 1267 (COR 15275)	4	-
Lythraceae				
Cuphea micrantha Kunth	Herb	Damasceno-Jr,G.A. 2408 (COR 10890); Takahasi, A. 785 (COR 15033); Takahasi, A. 994	1, 2, 4	-
Malpighiaceae				
Aspicarpa pulchella (Griseb.) O'Donell & Lourteig	Herb	Damasceno-Jr, G.A. 1306 (SP 365739); Takahasi, A. 1124 (COR 15208); Takahasi, A. 737 (COR 15014)	1, 2, 3	-
Banisteriopsis muricata (Cav.) Cuatrec	Liana	Takahasi, A. 896 (COR 15092)	3	-
Callaeum psilophyllum (A.Juss.) D.M.Johnson	Liana	Takahasi, A. 762 (COR 15019)	2	-
Dicella macroptera A.Juss.	Liana	Damasceno-Jr,G.A. 1328 (COR 9196)	1	-
Diplopterys lutea (Griseb.) W.R.Anderson & C.Davis	Liana	Damasceno-Jr,G.A. 1156 (COR 13882)	2	-
Diplopterys pubipetala (A. Juss) W.R. Anderson & C. Davis	Liana	André, C.B.D.S. 78 (COR 15839)	9	-
Heteropterys cf. *amplexicaulis* Morong	Liana	Takahasi, A. 1109 (COR 15199)	2	-
Heteropterys cochleosperma A.Juss.	Liana	André, C.B.D.S. 21 (COR 15837)	9	-
Heteropterys hypericifolia A.Juss.	Shrub	André, C.B.D.S. 80 (COR 15849)	9	-
Heteropterys cf. *tomentosa* A.Juss.	Liana	Souza, N. 9 (COR 15799)	9	-
Janusia guaranitica (A. St.-Hil.) A. Juss.	Liana	Takahasi, A. 819 (COR 15055); Pott, A. 9303 (CGMS 51180)	4, 7	-
Ptilochaeta densiflora Nied.	Tree	Damasceno-Jr,G.A. 1200 (COR 13614)	2	-
Thryallis laburnum S. Moore	Shrub	Damasceno-Jr,G.A. 1345 (COR 9408); Takahasi, A. 1358 (COR 15326)	1, 3	VU (CNNFlora)
Malvaceae				
Abutilon ramiflorum A.St.-Hil.	Shrub	Silva, R.H. 952 (CGMS 38823)	1	-
Ayenia tomentosa L.	Herb	Takahasi, A. 1081 (COR 15180); Takahasi, A. 1350 (COR 15320); André, C.B.D.S. 7 (COR 15798)	3, 4, 9	-
Corchorus hirtus L.	Herb	Damasceno-Jr,G.A. 1409 (COR 6434); Takahasi, A. 946 (COR 15118); Takahasi, A. 876 (COR 15079); Silva, R.H. 883 (CGMS 38815)	1, 4, 5, 8	-
Gaya pilosa K.Schum.	Shrub	Silva, R.H. 886 (CGMS 38816)	8	-
Helicteres lhotzkyana K.Schum.	Shrub	Matos-Alves, F. 222 (CGMS 18874); Damasceno-Jr,G.A. 1160 (COR 13677)	1, 2	-
Luehea candicans Mart.	Tree	Takahasi, A. 847 (COR 15069); Takahasi, A. 1306 (COR 15293); Silva, R.H. 890 (CGMS 38817)	1, 2, 8	-
Melochia parvifolia Kunth	Shrub	Takahasi, A. 977 (COR 15140); Silva, R.H. 892 (CGMS 38818)	3, 8	-
Melochia pyramidata L.	Shrub	Takahasi, A. 1085 (COR 15184)	3	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Pavonia sidifolia Kunth	Herb	Takahasi, A. 919 (COR 15102); Takahasi, A. 828 (COR 15061); Silva, R.H. 896 (CGMS 38819); Oliveira, P.P 329(COR 15844)	3, 4, 8, 9	-
Pseudobombax marginatum (A.St.-Hil.) A.Robyns	Tree	Takahasi, A. 1033	4	-
Sida coradinii Krapov.	Herb	Damasceno-Jr, G.A 1509 (COR 6015)	1	-
Sida cordifolia L.	Herb	Takahasi, A. 1375 (COR 15341)	4	-
Sida glomerata Cav.	Herb	Takahasi, A. 1281 (COR 15280)	4	-
Sida linifolia Juss. ex Cav.	Herb	Damasceno-Jr,G.A. 1417 (COR 2340); Takahasi, A. 1034 (COR 15166); Takahasi, A. 1090 (COR 15188); Oliveira, P.P 205 (COR 15819); Silva, R.H. 925 (CGMS 38826)	1, 3, 4, 9, 10	-
Sida rupicola Hassl. (Sida glabra Mill.)	Herb	Damasceno-Jr,G.A. 1311 (COR 13853); Takahasi, A. 1024 (COR 15161)	1, 2	-
Waltheria indica L.	Herb	Silva, R.H. 926 (CGMS 38827)	10	-
Waltheria operculata Rose	Herb	Takahasi, A. 771 (COR 15023); Takahasi, A. 711 (COR 15002); Takahasi, A. 944 (COR 15117)	2, 3, 4	-
Waltheria rotundifolia Schrank	Shrub	André, C.B.D.S. 6 (COR 15845)	9	-
Wissadula macrantha R.E.Fr.	Shrub	Damasceno-Jr, G.A. 1510; Takahasi, A. 986 (COR 15143)	1, 4	-
Molluginaceae				
Mollugo verticillata L.	Herb	Damasceno-Jr,G.A. 1322 (COR 13848); Damasceno-Jr,G.A. 1678 (COR 13847); Takahasi, A. 788 (COR 15036); Takahasi, A. 839; Silva, R.H. 895 (CGMS 38833)	1, 2, 3, 4, 8	-
Myrtaceae				
Eugenia aurata O. Berg	Shrub	Takahasi, A. 1115 (COR 5958); Silva, R.H. 934 (CGMS 38845)	3, 9	-
Eugenia punicifolia (Kunth) DC.	Shrub	Oliveira, P.P 204 (COR 15831)	9	-
Eugenia pyriformis Cambess.	Shrub	Takahasi, A. 774 (COR 5956); Takahasi, A. 794 (COR 15039)	2, 3	-
Myrcia laruotteana Cambess.	Shrub	Takahasi, A. 1264 (COR 15274)	4	-
Myrcia pyrifolia (Desv.) Nied.	Shrub	Souza, N. 33 (COR 15287)	9	-
Psidium guineense Sw.	Shrub	Silva, R.H. 922 (CGMS 38844)	10	-
Nyctaginaceae				
Reichenbachia paraguayensis (D.Parodi) Dugand & Daniel	Tree	Damasceno-Jr,G.A. 1348 (COR 9200)	1	-
Ochnaceae				
Ouratea aff. *castaneifolia* (DC.) Engl.	Tree	Takahasi, A. 1301 (COR 15288); Takahasi, A. 731	4, 5	-
Onagraceae				
Ludwigia lagunae (Morong) H. Hara	Shrub	Damasceno-Jr,G.A. 2414 (COR 10828)	1	-
Ludwigia leptocarpa (Nutt.) H. Hara	Shrub	Silva, R.H. 936 (CGMS 38849)	9	-
Orchidaceae				
Cyrtopodium virescens Rchb. f. & Warm.	Herb	Takahasi, A. 1114 (COR 15370); Damasceno-Jr, G.A. 2783 (CGMS 33893)	3, 6	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Oxalidaceae				
Oxalis barrelieri L.	Herb	Takahasi, A. 893 (COR 15089); Takahasi, A. 816 (COR 15052)	3, 4	-
Oxalis frutescens L.	Herb	Takahasi, A. 1126 (COR 15210); Takahasi, A. 1106	2, 6	-
Passifloraceae				
Passiflora foetida L.	Liana	Takahasi, A. 1402	6	-
Piriqueta corumbensis Moura	Herb	Takahasi, A. 1052 (COR 15176)	3	-
Piriqueta morongii Rolfe	Herb	Culau, R. 18 (COR 13702)	1	-
Turnera cf. *blanchetiana* Urb.	Herb	Damasceno-Jr,G.A. 3299 (COR 13150)	1	-
Turnera grandiflora (Urb.) Arbo	Herb	Takahasi, A. 663; Takahasi, A. 897 (COR 15093); Takahasi, A. 1260 (COR 15272); Damasceno-Jr,G.A. 2791 (COR 10914); André, C.B.D.S. 13 (COR 15809)	1, 3, 4, 6, 9	-
Turnera melochioides A. St.-Hil. & Cambess.	Herb	Oliveira, P.P 206 (COR 15841)	9	-
Turnera pumilea L.	Herb	Takahasi, A. 820 (COR 15056); Takahasi, A. 1381 (COR 15343)	4, 6	-
Turnera weddelliana Urb. & Rolfe	Herb	Damasceno 1419 (COR 13630); Damasceno-Jr,G.A. 1687 (COR 13698)	1, 2	-
Phyllanthaceae				
Phyllanthus orbiculatus Rich.	Herb	Takahasi, A. 1253 (COR 12394); Silva, R.H. 897 (CGMS 38852); Almeida, L.W. 45 (COR 15815)	4, 8, 9	-
Phytolaccaceae				
Microtea scabrida Urb.	Herb	Takahasi, A. 789 (COR 15037); Takahasi, A. 879 (COR 15081)	3, 5	-
Poaceae				
Axonopus compressus (Sw.) P.Beauv.	Herb	Takahasi, A. 969 (COR 15134); Takahasi, A. 1259 (COR 11749)	3, 4	-
Axonopus pressus (Steud.) Parodi	Herb	Oliveira, P.P 324 (COR 15821)	9	-
Axonopus suffultus (J.C.Mikan ex Trin.) Parodi	Herb	Takahasi, A. 952 (COR 11752)	6	-
Chloris elata Desv.	Herb	Takahasi, A. 796 (COR 11716)	3	-
Dactyloctenium aegyptium (L.) Willd.	Herb	Takahasi, A. 1207 (COR 11715)	2	-
Digitaria bicornis (Lam.) Roem. & Schult.	Herb	Takahasi, A. 1293 (COR 11717)	3	-
Digitaria insularis (L.) Mez ex Ekman	Herb	Damasceno-Jr, G.A. 1412; Oliveira, P.P 325 (COR 15796)	1, 9	-
Digitaria sanguinalis (L.) Scop.	Herb	Silva, R.H. 884 (CGMS 38855)	8	-
Eragrostis articulata (Schrank) Nees	Herb	Silva, R.H. 885 (CGMS 38856)	8	-
Eragrostis orthoclada Hack.	Herb	Takahasi, A. 1290 (CGMS 20374)	3	LC (IUCN)
Eragrostis pilosa (L.) P.Beauv.	Herb	Silva, R.H. 933 (CGMS 38875)	9	-
Eustachys distichophylla (Lag.) Nees	Herb	Takahasi, A. 1272 (COR 11721)	4	-
Gouinia latifolia (Griseb.) Vasey	Herb	Damasceno-Jr, G.A. 1416; Takahasi, A. 1021 (COR 11739)	1, 3	-
Leptochloa virgata (L.) P.Beauv.	Herb	Silva, R.H. 889 (CGMS 38867)	8	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Megathyrsus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs	Herb	Silva, R.H. 967 (CGMS 38863); Takahasi, A. 1211 (COR 11733); Takahasi, A. 981 (COR 15142); André, C.B.D.S. 18 (COR 15803)	1, 2, 3, 9	-
Melinis minutiflora P.Beauv.	Herb	Takahasi, A. 1029 (COR 11740)	3	-
Melinis repens (Willd.) Zizka	Herb	Damasceno-Jr,G.A. 1324 (COR 9194); Takahasi, A. 747 (COR 11735); Silva, R.H. 891 (CGMS 38858)	1, 3, 8	-
Mesosetum cayennense Steud.	Herb	Diamante, M. 292 (COR 15820)	9	-
Mesosetum chaseae Luces	Herb	Takahasi, A. 1204 (COR 11747); Takahasi, A. 957 (COR 11725)	4, 6	-
Microchloa indica (L.f.) P.Beauv.	Herb	Takahasi, A. 1172 (COR 11730); Takahasi, A. 898; Takahasi, A. 1351 (COR 15321); Silva, R.H. 920 (CGMS 38873)	2, 3, 4, 10	-
Oplismenus hirtellus (L.) P.Beauv.	Herb	Takahasi, A. 1274 (COR 11722)	4	-
Panicum exiguum Mez	Herb	Takahasi, A. 1183 (COR 15235); Takahasi, A. 1150 (COR 11741); Takahasi, A. 1276 (COR 11751)	2, 3, 4	-
Panicum millegrana Poir.	Herb	Takahasi, A. 1292 (COR 11727)	6	LC (IUCN)
Panicum sellowii Nees	Herb	Silva, R.H 938 (CGMS 38876)	9	-
Panicum stramineum Hitchc. & Chase	Herb	Silva, R.H. 968 (CGMS 38864)	1	-
Panicum trichoides Sw.	Herb	Takahasi, A. 883	5	-
Pappophorum pappiferum (Lam.) Kuntze	Herb	Takahasi, A. 855 (COR 11714)	2	-
Paspalum malacophyllum Trin.	Herb	Takahasi, A. 1273 (COR 11750); Takahasi, A. 1162 (COR 15226)	4, 6	-
Paspalum plicatulum Michx.	Herb	Takahasi, A. 1157 (COR 11743); Takahasi, A. 1249 (COR 11748); Silva, R.H. 921 (CGMS 38874)	3, 4, 10	-
Rugoloa polygonata (Schrad.) Zuloaga	Herb	Takahasi, A. 1234 (COR 11734)	2	-
Schizachyrium condensatum (Kunth) Nees	Herb	Takahasi, A. 999 (COR 11719)	4	-
Schizachyrium cf. *sanguineum* (Retz.) Alston	Herb	Damasceno-Jr,G.A. 1429 (COR 6410)	1	-
Setaria parviflora (Poir.) Kerguélen	Herb	Damasceno-Jr,G.A. 1495 (COR 6012); Takahasi, A. 870 (COR 11728); Takahasi, A. 1294 (COR 11718); Oliveira, P.P. 328 (15822)	1, 2, 3, 9	LC (IUCN), CR (CNNFlora)
Setaria vulpiseta (Lam.) Roem. & Schult.	Herb	Silva, R.H. 902 (CGMS 38859)	8	-
Sporobolus aeneus (Trin.) Kunth var. aeneus	Herb	Damasceno-Jr,G.A. 1323 (COR 6413)	1	-
Sporobolus indicus (L.) R.Br.	Herb	Damasceno-Jr,G.A. 2410 (COR 10930); Takahasi, A. 968 (COR 15133); Takahasi, A. 1255 (COR 15271); Oliveira, P.P 207 (COR 15832)	1, 3, 4, 9	-
Sporobolus monandrus Roseng., B.R.Arrill. & Izag.	Herb	Takahasi, A. 1016 (COR 15157); Takahasi, A. 787 (COR 15035); Takahasi, A. 982 (COR 11745); Takahasi, A. 1289 (CGMS 20378); Silva, R.H. 903 (CGMS 38860)	2, 3, 4, 6, 8	-
Sporobolus tenuissimus (Schrank.) Kuntze	Herb	Culau, R. 51 (COR 6424)	2	-
Steinchisma cf. *laxum* (Sw.) Zuloaga	Herb	André, C.B.D.S. 35 (COR 15813)	9	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Tripogon spicatus (Nees) Ekman	Herb	Damasceno-Jr, G.A. 1522; Takahasi, A. 1131 (COR 11729); Takahasi, A. 1154 (COR 11742); Takahasi, A. 1168 (COR 11746); Takahasi, A. 873 (COR 15078)	1, 2, 3, 4, 5	-
Urochloa adspersa (Trin.) R.D.Webster	Herb	Takahasi, A. 1277 (COR 11755)	4	-
Urochloa brizantha (Hochst. ex A. Rich.) R.D.Webster	Herb	Damasceno-Jr, G.A. 1394 (COR 6414); Takahasi, A. 1184 (COR 11732)	1, 2	-
Urochloa plantaginea (Link) R.D.Webster	Herb	Silva, R.H. 906 (CGMS 38861)	8	-
Polygalaceae				
Asemeia monninoides (Kunth) J.F.B.Pastore & J.R.Abbott	Herb	Culau, R. 30 (COR 13622)	1	-
Bredemeyera floribunda Willd.	Liana	Takahasi, A. 1101 (COR 15195); Takahasi, A. 1037 (COR 15168); Takahasi, A. 1038; Souza, N. 26 (COR 15826)	2, 3, 4, 9	-
Portulacaceae				
Portulaca amilis Speg.	Succulent	Silva, R.H. 969 (CGMS 38883); Takahasi, A. 1128 (COR 15211)	1, 2	-
Portulaca halimoides L.	Succulent	Takahasi, A. 1371 (COR 15337)	2	-
Portulaca hoehnei D. Legrand	Succulent	Pott, V.J. 7407 (CGMS 55952)	1	-
Portulaca mucronata Link	Succulent	Takahasi, A. 1218 (COR 15250); Takahasi, A. 809 (COR 15047); Takahasi, A. 1254 (COR 15270); Takahasi, A. 882 (COR 15083)	2, 3, 4, 5	-
Portulaca mucronulata D. Legrand	Succulent	Takahasi, A. 1193 (COR 15242); Takahasi, A. 970 (COR 15135); Takahasi, A. 1139 (COR 15216); Takahasi, A. 888 (Cor 15087)	2, 3, 4, 5	-
Portulaca pilosa L.	Succulent	Takahasi, A. 800 (COR 15041); Takahasi, A. 1305 (COR 15292)	3, 4	-
Portulaca umbraticola Kunth	Succulent	Takahasi, A. 1367 (COR 15333); Takahasi, A. 1361 (COR 15329)	3, 4	-
Talinum fruticosum (L.) Juss.	Succulent	Takahasi, A. 909 (COR 15099)	3	-
Rhamnaceae				
Gouania lupuloides (L.) Urb.	Liana	Damasceno-Jr,G.A.-Jr 1305 (COR 9190); Damasceno-Jr, G.A. 1176; Takahasi, A. 881	1, 2, 5	-
Ziziphus oblongifolia S. Moore	Tree	Damasceno-Jr, G.A. 5320 (CGMS 41018)	1	-
Rubiaceae				
Borreria capitata (Ruiz & Pav.) DC.	Herb	Damasceno-Jr,G.A. 1313 (COR 5320)	1	-
Borreria verticillata (L.) G.Mey.	Herb	Takahasi, A. 1190 (COR 15240); Takahasi, A. 1138 (COR 12405); Silva, R.H. 879 (CGMS 38885)	2, 4, 8	-
Cordiera concolor (Cham.) Kuntze	Tree	Takahasi, A.1407	6	-
Coutarea hexandra (Jacq.) K.Schum.	Shrub	Damasceno-Jr, G.A. 1405 (UB 30281); Takahasi, A. 906 (COR 12401); Souza, N. 32 (COR 15851); Silva, R.H. 916 (CGMS 38894)	1, 3, 9, 10	-
Randia armata (Sw.) DC.	Shrub	Takahasi, A. 743 (COR 12400); Silva, R.H. 923 (CGMS 38895)	3, 10	-
Spermacoce gracillima (DC.) Delprete	Herb	Damasceno-Jr,G.A. 1327 (COR 5321)	1	-

Continuation Table 2.

Species	Growth habit	Vouchers	Locality	Conservation status
Staelia thymoides Cham. & Schltdl.	Herb	Pott, A. 9279 (CGMS 37441); Silva, R.H. 904 (CGMS 38887)	7, 8	-
Tocoyena formosa (Cham. & Schltdl.) K.Schum.	Shrub	Damasceno-Jr,G.A. 1408 (COR 5323); Takahasi, A. 1146 (COR 12399); Takahasi, A. 805 (COR 15045)	1, 2, 3	-
Rutaceae				
Esenbeckia almawillia Kaastra	Shrub	Damasceno-Jr,G.A. 3295 (COR 13166)	1	-
Helietta puberula R.E. Fr.	Tree	Takahasi, A. 1176 (COR 15231); Takahasi, A. 1354 (COR 15323); Takahasi, A. 871 (COR 15077); Silva, R.H. 918 (CGMS 38900)	2, 4, 5, 10	-
Salicaceae				
Casearia gossypiosperma Briq.	Tree	Takahasi,A. 1086 (COR 15185); Takahasi, A. 1415; Oliveira, P.P 203 (COR 15852)	4, 6, 9	-
Casearia sylvestris Sw.	Tree	Takahasi, A. 1057 (COR 15178)	3	-
Xylosma venosa N.E.Br.	Tree	Silva, R.H. 927 (CGMS 38901)	10	-
Sapindaceae				
Serjania caracasana (Jacq.) Willd.	Liana	Takahasi, A. 1188 (COR 15238); Takahasi, A. 1027 (COR 15164)	2, 3	-
Serjania marginata Casar.	Liana	Damasceno-Jr,G.A. 1330 (COR 13705)	1	-
Thinouia paraguayensis (Britton) Radlk.	Liana	Damasceno-Jr,G.A. 1518 (COR 6089)	1	-
Urvillea laevis Radlk.	Liana	Damasceno-Jr,G.A. 1512 (COR 6081)	1	-
Sapotaceae				
Pouteria torta (Mart.) Radlk.	Tree	Takahasi, A. 1166 (COR 15228)	4	-
Smilacaceae				
Smilax cf. *fluminensis* Steud.	Liana	Takahasi, A. 1045 (COR 15173)	4	-
Verbenaceae				
Stachytarpheta matogrossensis Moldenke	Herb	Takahasi, A. 703; Takahasi, A. 1231 (COR 15258); Takahasi, A. 744; Takahasi, A. 886 (COR 15085); Takahasi, A. 1164	1, 2, 3, 5, 6	-

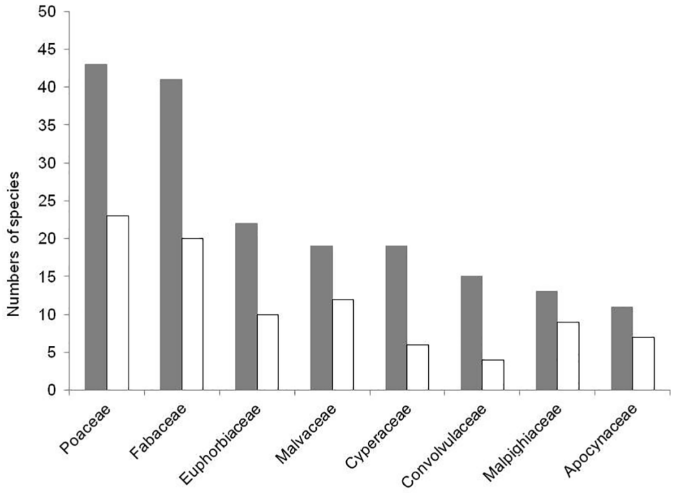

Figure 2. Number of species (gray bar) and genera (white bar) of the richest families found on the cangas at the Urucum Plateau, Western Border of Pantanal, MS.

E. Holzh. and *Borreria verticillata* (L.) G.Mey. In the seasonally wet areas we can find species such as *Ludwigia lagunae* (Morong) H. Hara, *Crotalaria pallida* Aiton, *Sporobolus indicus* (L.) R.Br. and *Eleocharis contracta* Maury ex Micheli.

Based on the species list of Flora do Brasil 2020, among the total number of recorded species, 177 (58.61%) are of wide distribution, occurring in almost all regions in Brazil, such as *Acrocomia aculeata* (Jacq.) Lodd. ex Mart., *Anadenanthera colubrina* (Vell.) Brenan, *Bromelia balansae* Mez, *Conyza bonariensis* (L.) Cronquist, *Handroanthus impetiginosus* (Mart. ex DC.) Mattos, *Myracrodruon urundeuva* Allemão, *Ludwigia leptocarpa* (Nutt.) H. Hara and *Urochloa brizantha* (Hochst. ex A. Rich.) R.D.Webster. Other species are recorded as common in other biomes, such as *Myrcia pyrifolia* (Desv.) Nied. (Amazon Rainforest), *Sida coradinii* Krapov. and *Zephyranthes cearensis* (Herb.) Baker (Caatinga), *Aspidosperma quirandy* Hassl. (Atlantic Forest), *Frailea cataphracta* (Dams) Britton & Rose, *Digitaria sanguinalis* (L.) Scop. and *Staelia thymoides* Cham. & Schltdl. (Pampas).

Twenty species are listed in the International Union Conservation of Nature and Natural Resources (IUCN 2018) as endangered species, and nine species in the Red Book of Brazilian flora (Martinelli & Moraes 2013), (Table 2). The species *Muellera variabilis* (RR.Silva & AMG.Azevedo) MJ.Silva & AMG.Azevedo, *Gomphrena centrota* E. Holzh., *Bonamia balansae* Hallier f. and *Bauhinia leptantha* Malme are considered as rare species because of their restricted distribution or the scarcity of information on the size of their populations (Giulietti et al. 2009). Two species are considered endemic to the ironstone outcrops at the Urucum Plateau: *G. centrota* (Tomás et al. 2010) and *Discocactus ferricola* Buining & Brederoo, being the latter also present in Morro do Mutum, Bolivia (Tomás et al. 2010, Takahasi & Meirelles 2014).

The herbaceous habit was the predominant growth form on ironstone outcrops in the Urucum Plateau (47.02%), probably due to the high species richness in the families Poaceae and Cyperaceae, and the high frequency of herbaceous species in Malvaceae, Fabaceae and Passifloraceae (Figure 3). Shrub (21.85%) and arboreal species (10.26%) were also common in these areas, with great contribution of Fabaceae, Euphorbiaceae, Malvaceae, Myrtaceae and Apocynaceae.

Lianas (13,91%) were represented by the families Convolvulaceae, Malpighiaceae and Apocynaceae mainly (Figure 3). Although succulent species represent only 6.29% of the richness of the local flora, they are quite conspicuous in the landscape, forming dense mats of vegetation composed of *Bromelia balansae* Mez, *Deuterochnonia meziana* Kuntze ex Mez, *Opuntia retrorsa* Speg. and rupicolous vegetation of *Portulaca* sp.

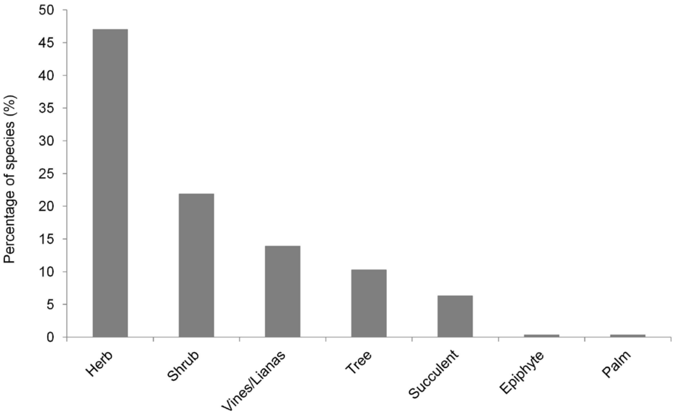

Figure 3. Growth habit of the species found on canga areas at the Urucum Plateau, Western Border of Pantanal, MS.

Considering the floristic associations present on the rocky outcrops at the Urucum plateau, we can distinguish ecological relationships between vegetation and edaphic variables, such as *Gomphrena centrota* E. Holzh., *Discocactus ferricola* Buining & Brederoo and *Polycarpaea corymbosa* (L.) Lam., that lodge directly on the hardened substrate, on slopes or in small cavities and fissures, covering rocky substrates; and soil islands, generally formed by mats of *Bromelia balansae* Mez and *Deuterocohnia meziana* Kuntze ex Mez, containing in their interior trees or shrubs of *Acrocomia aculeata* (Jacq.) Lodd. ex Mart., *Bauhinia pentandra* (Bong.) Vogel ex Steud., *Commiphora leptophloeos* (Mart.) J.B. Gillett, *Myracrodruon urundeuva* Allemão and *Tocoyena formosa* (Cham. & Schltdl.) K.Schum., among others (Takahasi 2010, Takahasi & Meirelles 2014, Takahasi 2015; Figure 4 F). At the edges of soil islands, there are also many herbaceous and annual species, such as *Borreria capitata* (Ruiz & Pav.) DC., *Calea rupicola* Chodat, *Mimosa bimucronata* (DC.) Kuntze, *M. xantocentra* Mart. and *Waltheria operculata* Rose, which desiccate completely during the dry season. Other species such as *Portulaca mucronata* Link, *Cipura formosa* Ravenna and *Zephyranthes cearensis* (Herb.) Baker occur in seasonally flooded sites at topographically lower areas (Takahasi & Meirelles 2014, Takahasi 2015, Figure 4 C).

About 58.28% of the species were found in only one of the ironstone outcrops at the Urucum Plateau, and none of the species was recorded in all 10 analyzed areas. The similarity índex (Table 3) in the composition of the angiosperm flora between the ironstone outcrops was low and ranged from 0 (Rabicho farm, P8 and the Municipal Natural Park Piraputangas, P10) to 41% (Pantanal Park Road, P1 and Band'alta farm, P2).

By crossing data contained in SpeciesLink (CRIA 2018), Flora do Brasil 2020 (2018), Jabot (2018) and checklists of Flora from Mato Grosso do Sul state (Pott & Pott 1996, Schutz 2014, Profice et al. 2015, Machate et al. 2016, Araújo & Trevisan 2018, Barbosa 2018, Bortolotto et al. 2018, Damasceno-Junior et al. 2018, Farinaccio & Simões 2018, Fiaschi 2018, Francener et al. 2018, Groppo et al. 2018, Guglieri-Caporal et al. 2018, Lobão et al. 2018, Loiola & Cordeiro 2018, Panfiglio et al. 2018, Proença et al. 2018, Roque et al. 2018, Sartori et al. 2018, Secco et al. 2018, Versieux et al. 2018, Zappi et al. 2018), it was verified that from the species presented here, 27 were not previously recorded for Mato Grosso do Sul and three species have no information of occurrence in Brazil (Table 4).

Discussion

Previous works on floristics, phytosociology and/or phenology indicated the occurrence of 243 species distributed in 66 botanical families, including pteridophytes (Takahasi 2010, Takahasi & Meirelles 2014, Takahasi 2015, Oliveira 2016), not included in this study. Thus, this study added 59 new occurrences of species of angiosperms to the ironstone outcrops flora in the Urucum Plateau. The high richness of species found, similar to other ferruginous outcrops areas (Jacobi et al. 2007, Mourão & Stehmann 2007, Viana & Lombardi 2007, Pifano et al. 2010, Jacobi & Carmo 2008b, Jacobi & Carmo 2011, Carmo & Jacobi 2013, Skirycz et al. 2014), may be related to the proximity of seasonal forest patches bordering these formations, and related to the existence of cavities that allow the accumulation of soil and water pools, resulting in microhabitats that enable a variety of plant associations (Jacobi & Carmo 2008a, Takahasi & Meirelles 2014).

The high turnover of species between the areas of ironstone outcrops sampled, together with the seasonality, where some species are only perceived during the rainy season, help to explain the high richness found in these environments. Another factor that contributes to species richness is the presence of subspontaneous and ruderal species from adjacent pastures, such as *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs and *Melinis minutiflora* P.Beauv.

Overall, species are established according to the topographic characteristics in the environment and the substrate granulometry, so that the structure and spatial-temporal distribution of the species are not homogeneous on ironstone outcrops (Takahasi & Meirelles 2014).

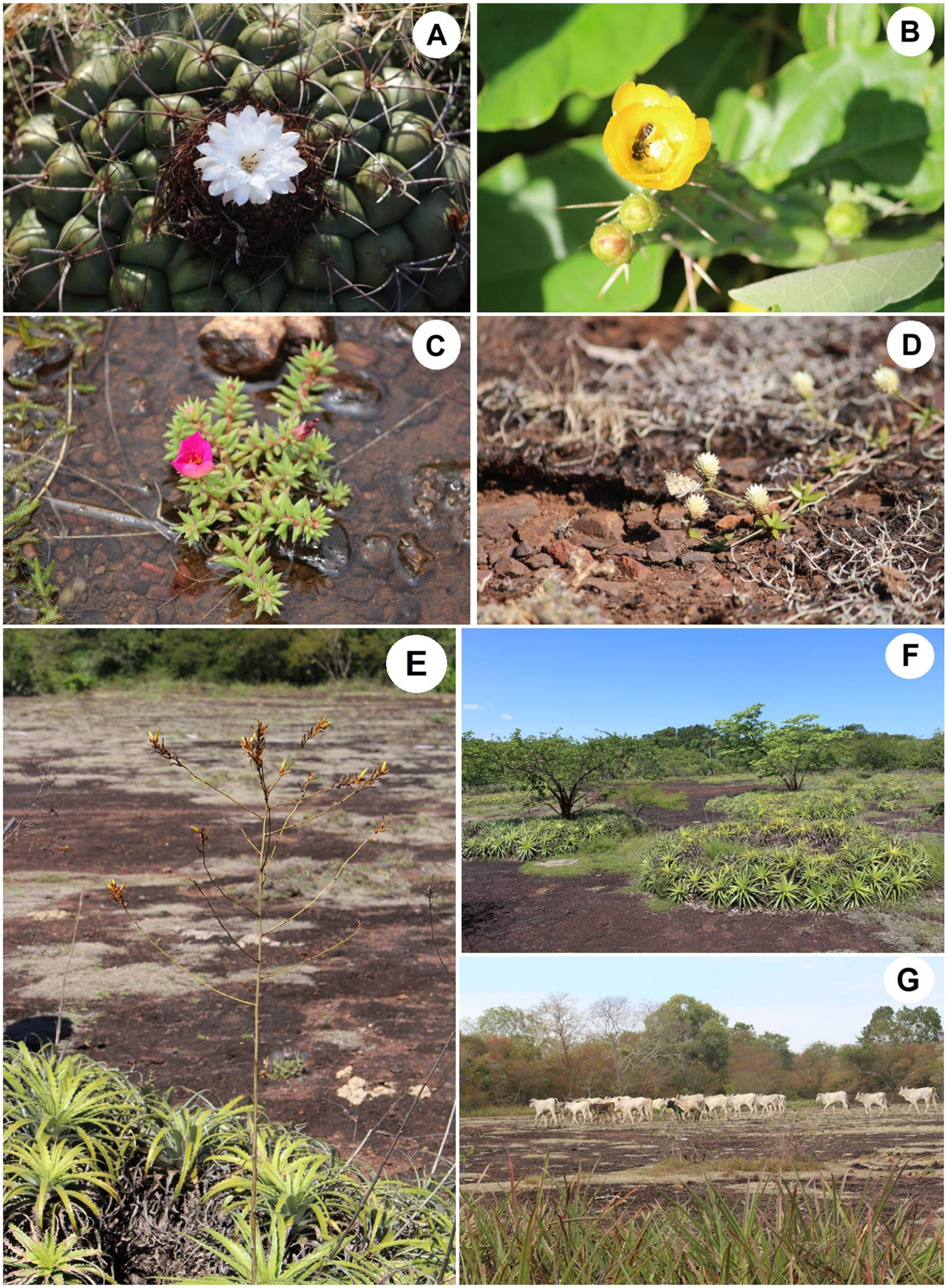

Figure 4. Species from the cangas plant community at the Urucum Plateau. A) *Discocactus ferricola*, B) *Opuntia retrorsa*, C) *Portulaca mucronata* in a flooded rocky substrate área, canga in the Band'alta farm, D) *Gomphrena centrota*, endemic species of the region, E) *Deuterocohnia meziana*. Cangas environments (Band'alta farm): F) Soil islands with densification of *Deuterocohnia meziana* and arboreal-shrub species in the center. In the background, seasonal forests bordering the rocky substrates, G) the vulnerability of the cangas of the region against anthropic pressure, e.g. by grazing livestock.

Table 3. Sorensen index among the cangas (P1-P10) at the Urucum Plateau, Western Border of Pantanal, MS. The numbers of localities are shown in Table 1.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
P1	1	0.418	0.333	0.236	0.176	0.095	0.118	0.143	0.127	0.063
P2		1	0.384	0.317	0.200	0.155	0.108	0.134	0.093	0.066
P3			1	0.370	0.158	0.143	0.158	0.203	0.237	0.170
P4				1	0.210	0.205	0.133	0.165	0.175	0.124
P5					1	0.069	0.043	0.120	0.030	0.053
P6						1	0.172	0.194	0.101	0.040
P7							1	0.200	0.119	0.105
P8								1	0.085	0
P9									1	0.068
P10										1

Table 4. List of species first mentioned for the state of Mato Grosso do Sul and for Brazil.

Species	**Determiner**	**Geographical distribution**	**Domain**	**Reference**
Acanthaceae				
Justicia cf. *harleyi* Wassh.	D.T. Azevedo	BA, MG	Cerrado, Caatinga	Cortês & Rapini (2013), Profice et al. (2015)
Amaranthaceae				
Alternanthera flavescens Kunth	L. Senna (VII/2015)	wide distribution	Amazon Rainforest, Cerrado, Atlantic Forest	Senna (2015)
Alternanthera rufa (Mart.) D.Dietr.	L. Senna (VII/2015)	BA, MG, SP, PR	Cerrado Caatinga	Senna (2015)
Amaryllidaceae				
Zephyranthes cearensis (Herb.) Baker	R. Oliveira	Northeast, TO, GO, MT, MG	Caatinga, Cerrado	Dutilh & Oliveira (2015)
Apocynaceae				
Forsteronia thyrsoidea (Vell.) Müll. Arg.	No determiner	wide distribution	Cerrado, Atlantic Forest	Koch et al. (2015)
Convolvulaceae				
Evolvulus cf. *chrysotrichos* Meisn.	R.S.Bianchini X/2003	MG, SP	Cerrado, Atlantic Forest	Simão-Bianchini & Ferreira (2015)
Evolvulus lithospermoides Mart.	R.S.Bianchini V/2009	PA, BA, CE, GO, MT, MG	Amazon Rainforest, Cerrado	Simão-Bianchini & Ferreira (2015)
Ipomoea cf. *hieronymi* (Kuntze) O'Donell	G. Staples V/2016	Bolivia, Argentina	no info	Missouri Botanical Garden (2018)
Cyperaceae				
Cyperus cuspidatus Kunth	A.P.Prata XI/2003	North, Northeast	Amazon Rainforest, Caatinga	Alves et al. (2015)
Cyperus subcastaneus D.A. Simpson	R.Trevisan VI/2008	BA, PE, MG	Caatinga, Cerrado	Alves et al. (2015)
Rhynchospora contracta (Nees) J.Raynal	A.P.Prata XI/2003	Northeast	Caatinga, Cerrado, Atlantic Forest	Alves et al. (2015)
Euphorbiaceae				
Manihot guaranitica Chodat & Hassl.	M. Mendoza I/2016	Argentina, Bolívia, Paraguai	No info	Missouri Botanical Garden (2018)

Continuation Table 4.

Species	Determiner	Geographical distribution	Domain	Reference
Fabaceae				
Chamaecrista supplex (Benth.) Britton & Killip	R.R Silva	wide distribution	Amazon Rainforest, Caatinga, Cerrado, Atlantic Forest	Souza & Bortoluzzi (2015)
Iridaceae				
Cipura formosa Ravenna	No determiner	North, MT, GO, BA	Cerrado	Chukr (2015)
Lamiaceae				
Mesosphaerum cf. *pectinatum* (L.) Kuntze	No determiner	Northeast, Sudeste, PA, PR, SC	Amazon Rainforest, Caatinga, Cerrado, Atlantic Forest	Harley et al. (2015)
Malvaceae				
Gaya pilosa K.Schum.	R.H.Silva III/2013	DF, MG, SP, PR, RS	Cerrado, Atlantic Forest	Esteves & Takeuchi (2015)
Sida coradinii Krapov.	A.Krapovickas X/2003	BA, PI	Caatinga	Bovini (2015)
Waltheria operculata Rose	G.L.Esteves X/2009	MT, GO, BA, PB, PE, RN,MG, RJ	Caatinga, Cerrado, Atlantic Forest, Pantanal	Esteves (2015)
Waltheria rotundifolia Schrank	P.P.Oliveira	BA, PE, PI, RN	Caatinga, Cerrado	Esteves (2015)
Myrtaceae				
Myrcia pyrifolia (Desv.) Nied.	No determiner	PA, AC, AM	Amazon Rainforest	Sobral et al. (2015)
Poaceae				
Digitaria sanguinalis (L.) Scop.	R.H.Silva III/2013	RS	Pampa	Canto-Dorow (2015)
Sporobolus tenuissimus (Schrank.) Kuntze	T.S.Filgueiras X/2001	wide distribution	Amazon Rainforest, Caatinga, Cerrado, Atlantic Forest	Longhi-Wagner (2015)
Polyganaceae				
Asemeia monninoides (Kunth) J.F.B.Pastore & J.R.Abbott	A.C.Aguiar IX/2003	Sudeste, TO, BA, DF, GO	Cerrado, Atlantic Forest	Pastore et al. (2015)
Portulacaceae				
Portulaca halimoides L.	A.O.P.Coelho VI/2010	Northeast, AP, PA, RR, TO, DF, GO, ES, MG, RJ	Amazon Rainforest, Caatinga, Cerrado, Atlantic Forest	Coelho & Zappi (2015)
Portulaca hoehnei D. Legrand	A.O.P.Coelho X/2004	MS	No info	Missouri Botanical Garden (2018)
Portulaca mucronulata D. Legrand	A.O.P.Coelho VI/2010	Argentina	No info	Missouri Botanical Garden (2018)
Rubiaceae				
Spermacoce gracillima (DC.) Delprete	P.Delpetre 1998	GO, TO	Cerrado	Cabral e Salas (2015)

The topographic development of these formations resulted in unique habitats such as fissures, cavities, small temporary ponds, depressions and exposed rocks, which differ from adjacent landscapes, constituting refuges for species adapted to xeric and mesic conditions (Jacobi et al. 2007, Jacobi & Carmo 2008b).

During the driest season of the year, most of the ironstone outcrops species present intense deciduousity, assuming a similar xeric aspect to that found in other ferruginous geosystems in Brazil (Mota et al. 2015). The difficulty for soil drainage, associated with climatic conditions in the region, gave rise to a prickly vegetation, physiognomically similar to the Caatinga, adapted to extreme conditions of evapotranspiration, thermal amplitude, underdeveloped soil, presence of heavy metals and drought periods in the region (Loureiro et al. 1982, Jacobi & Carmo 2008a, Jacobi et al. 2015). These adaptations may involve partial or total loss of aerial structures in the dry season, succulence, pseudo-bulbs in orchids, clonal reproduction, imbricate leaves, slow growth and CAM photosynthesis in order to resist desiccation cycles and subsequent rehydration (Jacobi et al. 2007, Jacobi & Carmo 2008b, Skirycz et al. 2014, Jacobi et al. 2015).

The predominance of species of wide distribution differs from that expected for ironstone outcrops in other regions of Brazil, where there are occurrences of exclusive species and different species from neighboring ecosystems (Skirycz et al. 2014). The deciduous forests in the Urucum Plateau that border the ironstone outcrops are characterized by the confluence of species from different biomes that surround it, keeping floristic relationships with the Bosque Seco Chiquitano in Bolivia (Jardim et al. 2003), and representatives from Chaco, Cerrado, Amazon Rainforest, Atlantic Forest and Southern Forests in the south and east (Rizzini 1997, Pott & Pott 2003, Tomás et al. 2010). In addition, it presents common species to the Caatinga, a vestige of a vegetative distribution pattern of the Pleistocene period. The period was characterized by a dry climate which resulted in the expansion of the seasonal forests and the retreat of the humid forests, allowing the connection of the previously disjunct vegetation of Northeast and Midwest regions of Brazil and Argentina (Prado & Gibbs 1993, Linares-Palomino et al. 2003).

The high proportion of herbaceous and arboreal-shrub species is explained by the representativeness of the families Fabaceae and Poaceae, similar to the results found for other plant communities in ferruginous outcrops in Brazil (Mourão & Stehmann 2007, Viana & Lombardi 2007, Pifano et al. 2010, Jacobi & Carmo 2011, Carmo & Jacobi 2013, Skirycz et al. 2014). On the other hand, the family Asteraceae, that is well represented in ironstone outcrops of other regions of the country (Mourão & Stehmann 2007, Viana & Lombardi 2007, Pifano et al. 2010, Ataíde et al. 2011), presented low species richness in the studied region. According to Rizzini (1997), the cangas are hardened ferrous formations and therefore have discontinuous vegetation and are typically covered by very specialized herbaceous vegetation, while on its edge woody species remain. The families Poaceae and Fabaceae are not abundant only on ironstone outcrops of the Urucum Plateau, but also among the herbaceous and woody groups, and in general between Angiosperms in Brazil (Forzza et al. 2010, BFG 2015).

Sørensen's similarity estimates found between the areas were low, with values below 0.5, which corroborates other studies indicating high beta diversity for these phytophysiognomies (Mourão & Stehmann 2007, Jacobi & Carmo 2008b, Pifano et al. 2010, Messias et al. 2012). The areas of Pantanal Park Road and Band'alta farm are the closest to each other, which justifies the highest similarity found. However, it should be noted that due to the species surveying method used in this study, sampling effort among the ironstone outcrops was not uniform. Thus, some common and abundant species may not have been listed for some of the ironstone outcrops because they represent species already cataloged for the environment, this way reducing similarity between some areas. In rupestrian grassland on ferruginous outcrops in Iron Quadrangle (Jacobi & Carmo 2008b) low proportion (5%) of common species was found among the analyzed areas, suggesting high beta diversity, probably resulting from the topographic and microclimatic variations in the habitat between areas.

Recent studies have updated the occurrence of some of the species recorded here for Mato Grosso do Sul such as *Tradescantia boliviana* (Hassk.) J.R.Grant (Pellegrini et al. 2017), *Deuterohconia meziana* Kuntze ex Mez (Schutz 2014), *Dyckia excelsa* Leme (Paggi et al. 2015) and *Tarenaya eosina* (J.F.Macbr.) Soares Neto & Roalson, a species considered endemic to Paraguay (Costa-e-Silva 2000, Soares-Neto et al. 2018). *Portulaca hoehnei* D. Legrand is not a species of occurrence for Brazil, although its holotype is from the region of Corumbá (Hoehne R 3565). New occurrences of species in the ironstone outcrops of the Urucum Plateau demonstrate the need for continuous research to update the knowledge about the size and distribution of the species that occur in these formations, and the level of conservation in which they are found.

Although the ironstone outcrops in the Urucum Plateau do not directly undergo mineral extractive activity, due to their location at the foothill and relative distance of the mines of iron and manganese extraction, these environments are under intense anthropic action. Extraction of ornamental species such as orchids, bromeliads and cacti for sale at local fairs, grazing by cattle, fire action and removal of local vegetation by owners are pressures undergone by the flora from these areas (Takahasi & Meirelles 2014, Figure 4 G).

Even in a situation of maximum vulnerability, less than 1% of canga areas in Brazil are included in Full Protected Conservation Units, such as National and State Parks (Carmo et al. 2012). The high diversity and presence of endemic, rare, endangered and/or not yet cataloged species for the Urucum Plateau region, reinforces the need for local conservation units that can guarantee the preservation of these species, since the environmental protection areas in the region are insufficient to guarantee the maintenance of typical populations from this habitat (Tomás et al. 2010). In addition, our data can significantly contribute for changing the conservation status of some species, since only 13% of the rare species present in ferruginous geosystems from Brazil are cited in the List of Endangered Species, in large part due to insufficient data for this type of environment (Giulietti et al. 2009, Jacobi et al. 2015).

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Author Contributions

Michele Soares de Lima: Substantial contribution in the concept and design of the study, contribution to data collection, contribution to data analysis and interpretation, contribution to manuscript preparation, contribution to critical rrevision, adding intelectual content.

Adriana Takahasi: Substantial contribution in the concept and design of the study, contribution to data collection, contribution to data analysis and interpretation, contribution to manuscript preparation, contribution to critical rrevision, adding intelectual content.

Geraldo Alves Damasceno-Junior: Substantial contribution in the concept and design of the study, contribution to data collection, contribution to data analysis and interpretation, contribution to manuscript preparation, contribution to critical rrevision, adding intelectual content.

Andréa Cardoso Araujo: Substantial contribution in the concept and design of the study, contribution to data analysis and interpretation, contribution to manuscript preparation, contribution to critical rrevision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Diet and ecomorphology of predator fish species of the Amazonian floodplain lakes

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Abstract: Amazonian floodplain lakes host a high diversity of predatory fish which coexist and exploit the high diversity of available prey. Morphology could be the characteristic most closely associated with their preferred feeding sources (prey). However, it is unclear whether this association is direct or indirect. If it is indirect, swimming performance or preferential position in the water column could be the most evident characteristic. To examine the degree to which fish morphology of predator fish species is correlated to their dietary inputs, we compared the existence of morphological and feeding dissimilarity among eight predator species with the association between predator morphologies and preferred prey. We collected, measured, and sampled the stomach contents of fish from two lowland floodplain lakes associated with the Solimões River, Brazil, in May, August, and November of 2014. Of 187 collected fish across eight species, five species showed fish to be the most important item in their diets and three preferentially ate shrimp. Principal components analyses of ecomorphological attributes divided the species according to their ability to find the prey, swimming performance of the predator, and prey size. While there was significant distinction between the varying morphologies of predators, we were unable to distinguish between the specific diet of these species and did not find a correlation between morphology and feeding. These results are likely due to the fact that there is great abundance and diversity of available prey in the Amazonian floodplain lakes, so opportunistic feeding may be the primary foraging strategy of predator fish species living in these environments.
Keywords: *Feeding behavior, Morphological Attributes, Predation, Amazonian floodplain lakes.*

Dieta e ecomorfologia de peixes predadores em lagos de várzea da Amazônia

Resumo: Os lagos da várzea amazônica abrigam uma elevada riqueza de peixes predadores, com características morfológicas distintas, possibilitando explorar com sucesso várias presas disponíveis. Estas características morfológicas podem ser a associação mais próxima com suas fontes de alimentação preferidas (presa). Todavia, esta associação pode ser de forma direta ou indireta. Neste último caso, o desempenho da natação ou a posição preferencial na coluna d'água pode ser uma característica mais evidente. Para examinar o grau com que a morfologia de peixes predadores está correlacionada com seus itens alimentares, foram comparadas a existência de dissimilaridade morfológica e de alimentação entre oito espécies predadoras e a associação entre suas morfologias e suas presas. Foram coletados, medidos e amostrados o conteúdo estomacal de peixes de dois lagos de várzea associados ao rio Solimões, nos meses de maio, agosto e novembro de 2014. Dos 187 peixes coletados, em oito espécies, cinco mostraram que peixe era o item mais importante em suas dietas e três apresentaram preferência por camarão. A análise dos componentes principais dos atributos ecomorfológicos dividiu as espécies de acordo com a capacidade de encontrar sua presa, o desempenho de natação do predador e o tamanho da presa. Embora apresentasse distinção significativa entre suas características morfológicas, não foi encontrado distinção entre a dieta dessas espécies e nem correlação entre morfologia e alimentação. Esses resultados provavelmente se devem ao fato de que há grande abundância e diversidade de presas disponíveis nos lagos da planície de inundação da Amazônia, de modo que a alimentação oportunista pode ser a principal estratégia de forrageamento das espécies de peixes predadores que vivem nesses ambientes.
Palavras-chave: *Comportamento alimentar, Atributos Morfológicos, Predação, Lagos de várzea amazônicos.*

Introduction

The Amazon basin displays strong spatial heterogeneity (Lowe-McConnell 1999) coupled to marked seasonal changes associated with the hydrological cycle (Junk et al. 1989). This huge and highly dynamic environment hosts the highest freshwater fish diversity on Earth, with more than 2,411 fish species already described (Reis et al. 2016). Floodplain lakes adjacent to whitewater rivers are important components of the Amazon basin landscape, are the most productive area of the basin (Junk et al. 2011), and encompass several habitats that should be considered when studying fish diversity (Saint-Paul et al. 2000, Freitas et al. 2014, Siqueira-Souza et al. 2016a).

Amazonian fish evolved to display several morphological, behavioral, and physiological adaptations to successfully exploit the habitats of floodplain areas (Val & Almeida-Val 1995, Freitas et al. 2010), including areas of open-water, macrophyte meadows, and flooded forests. Each of these habitats change greatly over the year as a consequence of the flood pulse (Junk et al. 1989) and subsequently show perceptible effects on fish assemblages (Siqueira-Souza et al. 2016a). The environmental changes of the Amazonian floodplain areas are dictated by variations in water level, have been associated with the life history strategies of fishes living in these areas (Sanchez-Botero et al. 2003, Anjos et al. 2008, Correa et al. 2008, Duarte et al. 2010). Ultimately these environmental changes determine food availability (Soares et al. 1986, Winemiller 1989, Mérona & Rankin-de-Mérona 2004, Carvalho et al. 2017).

The diet of fish species is strongly driven by both the availability of prey items (Winemiller 1989, Wootton 1990, Luz-Agostinho et al. 2008, Correa & Winemiller 2014) and the ability of predator species to capture prey (Schoener 1971, Agostinho et al. 1997, Abrams 2006). This ability is dependent on specific morphological adaptations (Adite & Winemiller 1997, Hugueny & Pouilly 1999, Pouilly et al. 2003, Teixeira & Bennemann 2007, Mazzoni et al. 2010, Pagotto et al. 2011, Siqueira-Souza et al. 2016b). The relationships between morphology and feeding behavior are addressed through an examination of ecomorphology (Wikramanayake 1990, Winemiller 1991, Teixeira & Bennemann 2007, Mazzoni et al. 2010, Sampaio et al. 2013). Ecomorphological studies have shown a relationship between feeding items and mouth size or position and the type and size of their prey (Gatz Jr. 1979, Piorski et al. 2005, Cochran-Biderman & Winemiller 2010), as well as between size and shape of fins and swimming or maneuverability (Keast & Webb 1966, Gatz Jr. 1979). In the Amazon basin, multiple research groups have already employed an ecomorphological analysis approach on Amazonian fish groups to elucidate the ecological relationships between feeding behavior, swimming ability, and habitat use preferences with morphology (e.g., Pouilly et al. 2003, Freitas et al. 2005, Siqueira-Souza et al. 2016b).

The biotic interactions most commonly associated with fish assemblage structure are competition and predation (Winemiller 1989, Rodriguez & Lewis 1997). The importance of predation as a driver for fish assemblage structure is well-established (Wootton 1990, Csányi & Dóka 1993, Nowlin et al. 2006, Heinlein et al. 2010), including for Neotropical basins (Rodríguez & Lewis 1997, Okada et al. 2003, Petry et al. 2010). Predation has been shown to not only promote more rapid evolutionary change through the removal of more vulnerable animals (Nowlin et al. 2006) but can also clearly affect prey behavior (Wootton 1990). The fish diversity in Amazonian floodplain areas could be related to biotic interactions, such as predation, since around 30% of fish species living in these areas are carnivorous (Freitas et al. 2010). Nevertheless, the mechanisms acting to promote this high level of coexistence of species with similar niches have yet to be clearly identified. Dias et al. (2017) studied fish assemblages of the Paraná River floodplain and proposed that predator selectivity and feeding overlap are mediated by food availability, but they did not consider morphological aspects of these predators. In this study, we aim to fill these research gaps by addressing the following questions: Is there a correlation between morphology and diet of Amazonian predator fish? Do predatory fish uniformly share the feeding items? Are the ecomorphological characteristics similar among predator fish species? There are two opposing processes that potentially mediating the coexistence of these predatory species which could be identified with the answer to these questions: (i) the availability of prey is limited and predators need to develop strategies to avoid a over-predation of some specific preys, where in turn we would expect a high correlation between morphology and diet; and (ii) the availability of prey is high and fish morphologies are determined by phylogenetic process.

Material and Methods

1. *Study area*

Fish were collected at two floodplain lakes on the lower stretch of the Solimões River (Amazon Basin): Sacambú (-3.306744S, -60.243298W) and Central (-3.253823S, -59.970098W) lakes (Fig. 1), in May, August and November of 2014. Both are typical floodplain lakes, remaining connected with the Solimões River during high water season (May through July) and disconnected during low water season (October through December) (Junk et al. 1989). As island floodplain lakes, they are originated by the strong fluvial dynamic of the Solimões River (Carvalho et al. 2001, Siqueira-Souza et al. 2016a).

2. *Sampling*

Eight fish species abundant in Amazonian floodplain lakes were chosen and assigned as carnivorous with tendency to piscivory (Mérona & Rankin-de-Mérona 2004, Soares et al. 2007, Anjos et al. 2008), nominally: *Pygocentrus nattereri* (Kner 1858), *Serrasalmus rhombeus* (Linnaeus 1766), *Rhaphiodon vulpinus* (Spix & Agassiz 1829), *Hydrolycus scomberoides* (Cuvier 1816), *Plagioscion squamosissimus* (Heckel 1840), *Cichla monoculus* (Spix & Agassiz 1831), *Acestrorhynchus falcirostris* (Cuvier 1819) and *Hoplias malabaricus* (Bloch 1794).

The fish samples in each lake were realized in three types of habitat: open water; aquatic macrophytes, predominantly composed of *Pistia stratiotes*, *Eichhornia crassipes*, *Paspalum repens* and *Paspalum fasciculatum*; and flooded forest, used by several species for shelter and feeding. Fish were caught with gillnets of standardized dimensions (15 x 2 meters) and mesh sizes of 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 mm between opposite knots. Three groups of identical gillnets were simultaneously deployed in three different places on each lake. Additionally, we deployed line and hook baited with freshwater shrimp to catch *C. monoculus.* Captured fish were subsequently euthanized with thermal shock, identified, and stored on ice. After capture, all samples were then transported to the Laboratory of Fish Ecology, at the Federal University of Amazonas, for stomach content analyses and morphometric measurement.

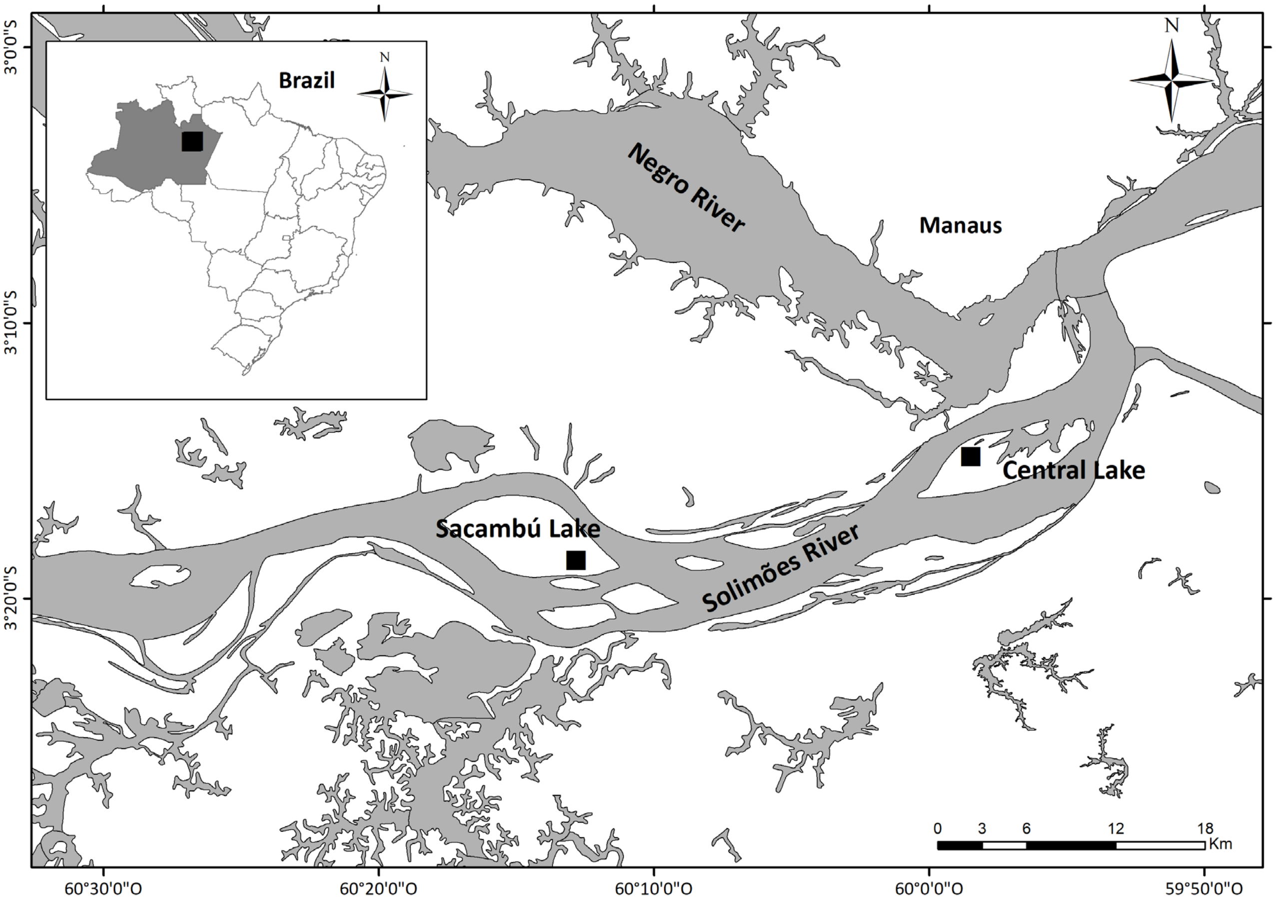

Figure 1. Study area indicating the two floodplain lakes on the lower stretch of the Solimões River: Lake Sacambú and Lake Central (Amazon Basin, Brazil), where fishes were collected.

3. *Ecomorphological attributes*

Ecomorphological analyses were conducted on captured adult fish, classified using the L_{50} of the species when references were available (Vazzoler 1996, Amadio & Bittencourt 2005) or working only with largest individuals, so as to avoid potentially misleading characteristics of different/earlier developmental stages. We took a total of 18 different morphometric measures on each fish, with the aid of an ichthyometer and a caliper with an accuracy of 0.01 m (Fig 2), following pre-established protocols from the literature (Gatz Jr. 1979, Watson & Balon 1984, Wikramanayake 1990, Winemiller 1991). These morphometric measures were then employed to estimate 13 ecomorphological attributes, which could reflect the trophic ecology of the species with clearly delineated interpretations (Table 1).

4. *Dietary analysis*

Stomachs were taken after a ventral incision. Feeding items were identified using a stereomicroscope and clustered into five categories: fish (including scales, bones, fins, and complete fish), shrimp, insect, fruit/seed, and others (i.e., botanical and animal material which could not be included into the previous categories, such as roots of macrophyte plants, feathers, etc.).

To estimate the relative contribution of each feeding item, we employed the modified points method (Catella & Petrere Jr. 1996), to obtain the proportion of each feeding item in relation to the total stomach content, and the index of occurrence frequency (IOF), reporting both in percentage (Hynes 1950, Hyslop 1980). After this calculation, we estimated the index of feeding importance (IFI), substituting the volume percentage by estimated percentage of point method for each item following the technique of Kawakami & Vazzoler (1980). Given that shrimp was used as bait for the capture of *C. monoculus*, this item was included only if there was more than one individual found in the stomach content.

5. *Data analysis*

Two Principal Component Analyses (PCA) were performed to order fish species by feeding items and ecomorphological attributes. The first PCA treated fish species as objects and IFI as descriptors. The second PCA maintained fish species as objects and estimated ecomorphological attributes as descriptors. The interpreted principal components were those with eigenvalues higher than broken-stick estimates (McCune & Mefford 1997), since this criterion selects only the axis with eigenvalues higher than would be randomly expected (King & Jackson 1999). Two PerMANOVA were performed. The first was conducted to test the hypothesis of identical feeding item partitioning among species, using a matrix of Bray–Curtis distance based on the relative volume of each feeding item. The second was performed to test the hypothesis of identical morphologies among species. It was based on a matrix of

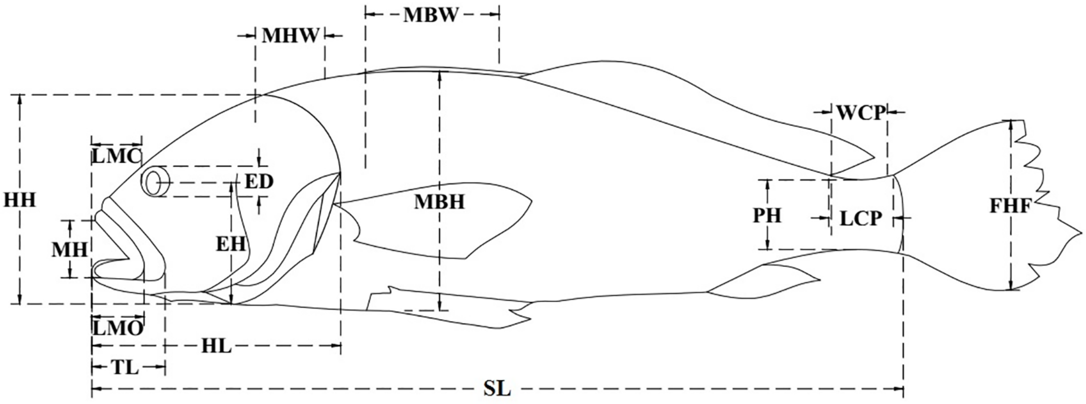

Figure 2. Morphometric measures taken on each fish, where: standard length (SL); head length (HL); head height (HH); maximum body height (MBH); maximum body width (MBW); maximum head width (MHW); eye height (EH); eye diameter (ED); eye area (EA), determined as $\pi * r^2$; width of mouth (WM); mouth height (MH); length of muzzle closed (LMC); length of muzzle open (LMO); tooth length (TL); length of caudal peduncle (LCP); peduncle height (PH); width caudal peduncle (WCP), and fin height flow (FHF).

Table 1. Relationship of the 13 attributes generated from the linear measurements and used in the ecomorphological analyzes.

Ecomorphological Attributes	Code	Formula	Description	Author
Compression index	CI	(MBH)/(MBW)	High values indicate lateral compression of the fish, which is expected when they occupy habitats with low water velocity.	(Gatz, 1979a; Watson & Balon, 1984; Pouilly et al., 2003)
Relative position of eyes	RPE	(EH)/(HH)	Perception of food and preferential habitat.	(Gatz, 1979a)
Relative area of eye	RAE	(EA)/(SL)	Perception of food, position in water column.	(Gatz, 1979a)
Relative length of caudal peduncle	RLCP	(LCP)/(SL)	Predators with good swimming for chase.	(Watson & Balon, 1984; Oliveira et al., 2010)
Relative width of head	RHW	(MHW)/(MBW)	Particle size of food and prey size.	(Winemiller, 1991; Willis et al., 2005)
Relative height of head	RHH	(HH)/(MBH)	Particle size of food and prey size.	(Winemiller, 1991; Willis et al., 2005)
Relative length of head	RHL	(HL)/(SL)	Particle size of food and prey size.	(Watson & Balon, 1984)
Relative width of mouth	RMW	(WM)/(SL)	Particle size of food and prey size.	(Gatz, 1979a)
Relative height of mouth	RHM	(MH)/(SL)	Particle size of food and prey size, hydrodynamic morphology.	(Watson & Balon, 1984)
Appearance of the mouth	AM	(MH)/(WM)	Type of prey.	(Beaumord, 1991)
Relative opening of the mouth	ROM	(TL)/(SL)	Particle size of food and prey size.	(Teixeira & Bennemann, 2007)
Protrusion index	PI	(LMC)/(LMO)	Particle size of food and prey size.	(Gatz, 1979a; Cochran-Biederman & Winemiller, 2010)
Peduncle compression Index	PCI	(PH)/(WCP)	Swimming type, affecting performance in starts.	(Watson & Balon, 1984)

Euclidean distances estimated on the ecomorpohological attributes estimates. This analysis tests the hypothesis of divergence among fish species by the centroid of estimated distance measures (Anderson & Walsh 2013).

A Partial Mantel test was used to test the hypothesis that diet and morphology of these species are not correlated. This test was performed using three distance matrices: (i) using feeding of items as raw data to estimate Bray-Curtis distances, (ii) employing ecomorphological attributes as raw data and estimates of Euclidean distance and (iii) using phylogenetic distances among species following Tamura et al. (2004) and Tamura et al. (2013). The Partial Mantel test estimated the partial correlation between distances matrixes measured among feeding items and ecomorphological attributes conditioned to the phylogenetic distance matrix.

All analyses were done using the package Vegan (Oksanen et al. 2011) in the software R (R Development Core Team, 2012).

Results

In total, we examined 187 stomachs from the eight fish species. Of these, 27 were empty and 61 contained completely digested feeding items so were not included in the analyses. The analyses were performed on the remaining 99 fish. Stomach items of these 99 fish were identified and fish was the most consumed food item for five of the eight predatory species (Table 2). Of these predators, *P. squamosissimus*, *H. scomberoides*, and *C. monoculus* exhibited a high level of consumption of shrimp. Only *P. nattereri* showed a substantial consumption of fruit/seeds and other feeding items (Table 2).

The first PCA, using RV of feeding items as descriptors, generated two principal components explaining 82.79% of the variance, with shrimp, fruit/seed and others contribution for the first axis; and fish, shrimp and others for the secondary axis (Table 3). The first component (PC1) explained 45.68% of the variance with *P. squamosissimus*, *H. scomberoides* and *C. monoculus* exhibiting the high positive score, due to their higher preference for shrimp, and *P. nattereri* exhibiting the most negative score, due to their diet including fruits, seeds and others items (Fig. 3). The second principal component (PC2) explained 37.11% of the variance and discriminated *H. malabaricus* and *P. nattereri* with high fish consumption (Fig. 3).

The estimated mean of the ecomorphological attributes for species and their standard deviation are seen in Table 4. The PCA using the ecomorphological attributes as descriptors created two first components explaining 90.58% of the variance. The first component concentrated 47.89% of the variance and discriminated, in opposing quadrants, a group associated with prey sizes and swimming ability, composed of high bodied fishes as *S. rhombeus* and *P. nattereri*, from a group related to the type of prey, composed of *R. vulpinus* and *H. scomberoides* (Fig. 4). The second component explained 42.69% of the variance. It was efficient to discriminate four species by their hydrodynamics: *H. malabaricus*, *A. falcirostris*, *P. squamosissimus* and *C. monoculus*, from some species with high maneuverability, such as the two piranha species, *S. rhombeus* and *P. nattereri*, (Fig. 4).

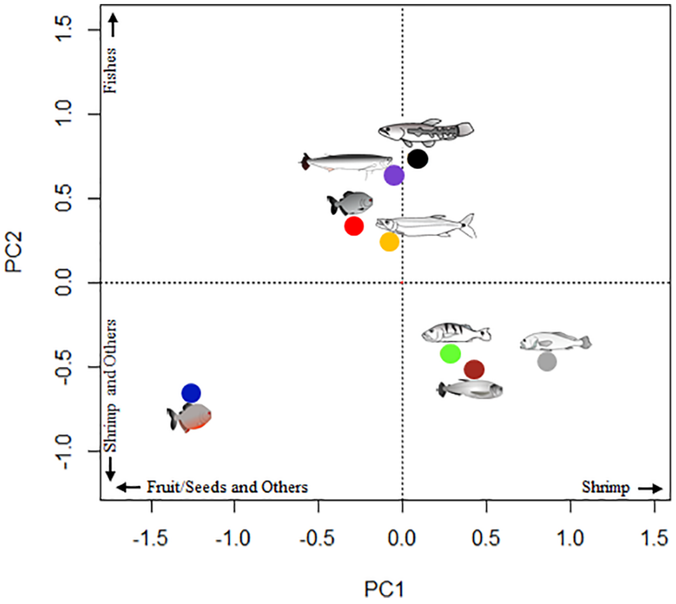

Figure 3. Results of the Principle Components Analysis, with the matrix of indices being dietary sources for eight fish species, identified as: ● *Rhaphiodon vulpinus*, ● *Hydrolycus scomberoides*, ● *Serrasalmus rhombeus*, ● *Pygocentrus nattereri*, ● *Acestrorhynchus falcirostris*, ● *Hoplias malabaricus*, ● *Plagioscion squamosissimus* and ● *Cichla monoculus*.

Corroborating the patterns observed in both PCAs, the perMANOVA did not provide evidence for differences among species by their feeding items (pseudo-F = 0.947, df = 1, 6, $p > 0.05$). The second perMANOVA, however, yielded significant differences among these eight species using their ecomorphological attributes (pseudo-F = 30.796, df = 1, 136, $p < 0.05$).

Table 2. Index of Food Importance (IFI) of eight predatory species. For each species listed, it includes the number of stomachs with analyzed gastric content (N); and variation of the standard length (SL) of the individuals analyzed.

			Index of Food Importance (%)				
Species	**N**	**SL (mín-máx)**	**Fish**	**Insects**	**Shrimp**	**Fruit/Seeds**	**Others**
Acestrorhynchus falcirostris	5	20.5 – 32.5	86.84	0	10.53	0	2.63
Hoplias malabaricus	4	19 – 28	93.33	3.33	3.33	0	0
Cichla monoculus	25	20.5 – 34.5	37.97	0.25	55.58	0	6.2
Plagioscion squamosissimus	9	18 – 24	7.55	2.83	89.15	0	0.47
Hydrolycus scomberoides	12	15 – 22.5	28.24	0.46	66.67	0	4.63
Rhaphiodon vulpinus	8	26 – 37.5	91.84	3.06	3.06	2.04	0
Serrasalmus rhombeus	16	13.5 – 18	91.88	0.88	0.22	1.64	5.37
Pygocentrus nattereri	20	15.5 – 19.5	54.86	0.75	4.4	10.55	29.44

Table 3. Principal component analysis results for the first two axes calculated for the food items.

food items	**PC 1**	**PC 2**
Fish	-0.5048	0.9393
Insects	0.3037	0.5432
Shrimp	0.8126	-0.7161
Fruit/Seed	-0.9517	-0.3691
Others	-0.8884	-0.6076
Variance (%)	**45.68%**	**37.11%**
Total variance		**82.79**

Table 4. Estimated values of mean and standard deviation of 13 ecomorphological attributes obtained from eight predatory species, including abundance of species (N), and amplitude of the standard length (SL) of the species.

Attributes	**Species**							
	A. falcirostris	***H. malabaricus***	***C. monoculus***	***P. squamosissimus***	***H. scomberoides***	***R. vulpinus***	***P. nattereri***	***S. rhombeus***
CI	1.68 ± 0.23	1.32 ± 0.08	2.14 ± 0.13	2.02 ± 0.10	3.19 ± 0.38	2.42 ± 0.24	2.91 ± 0.31	3.67 ± 0.37
RPE	0.67 ± 0.05	0.74 ± 0.10	0.74 ± 0.03	0.67 ± 0.04	0.69 ± 0.04	0.74 ± 0.07	0.60 ± 0.04	0.60 ± 0.04
RAE	0.05 ± <0.01	0.03 ± <0.01	0.10 ± 0.01	0.05 ± <0.01	0.06 ± <0.01	0.05 ± <0.01	0.06 ± 0.01	0.07 ± 0.01
RLCP	0.05 ± <0.01	0.11 ± <0.01	0.13 ± 0.01	0.19 ± 0.01	0.02 ± <0.01	0.03 ± 0.01	0.05 ± 0.01	0.04 ± 0.01
RHW	0.86 ± 0.07	0.89 ± 0.05	0.98 ± 0.04	0.93 ± 0.04	1.08 ± 0.10	0.88 ± 0.07	1.06 ± 0.04	1.05 ± 0.11
RHH	0.73 ± 0.06	0.69 ± 0.03	0.72 ± 0.03	0.75 ± 0.04	0.58 ± 0.06	0.75 ± 0.08	0.60 ± 0.04	0.51 ± 0.03
RHL	0.28 ± <..01	0.30 ± 0.02	0.33 ± <0.01	0.30 ± 0.01	0.24 ± 0.06	0.19 ± <0.01	0.34 ± 0.05	0.33 ± 0.01
RMW	0.07 ± 0.01	0.13 ± 0.02	0.16 ± 0.01	0.15 ± 0.01	0.08 ± 0.02	0.05 ± 0.01	0.13 ± 0.01	0.11 ± <0.01
RHM	0.17 ± 0.01	0.16 ± 0.01	0.18 ± <0.01	0.16 ± 0.01	0.24 ± 0.01	0.18 ± 0.01	0.15 ± 0.01	0.14 ± 0.03
AM	2.23 ± 0.41	1.27 ± 0.15	1.14 ± 0.07	1.07 ± 0.11	2.93 ± 0.50	3.29 ± 0.71	1.11 ± 0.14	1.26 ± 0.30
ROM	0.19 ± <0.01	0.18 ± 0.01	0.19 ± 0.01	0.17 ± 0.04	0.17 ± 0.02	0.14 ± <0.01	0.15 ± 0.01	0.14 ± 0.01
PI	0.91 ± 0.06	0.75 ± 0.05	0.83 ± 0.13	0.71 ± 0.11	0.49 ± 0.06	0.51 ± 0.04	0.81 ± 0.07	0.77 ± 0.06
PCI	1.39 ± 0.17	2.01 ± 0.16	1.40 ± 0.10	1.63 ± 0.26	2.19 ± 0.21	1.69 ± 0.28	1.81 ± 0.23	1.82 ± 0.44
N	15	7	20	21	9	11	32	23
SL	20.5 – 32.5	19 – 28	20.5 – 34.5	18 – 24	15 – 22.5	26 – 37.5	15.5 – 19.5	13.5 - 18

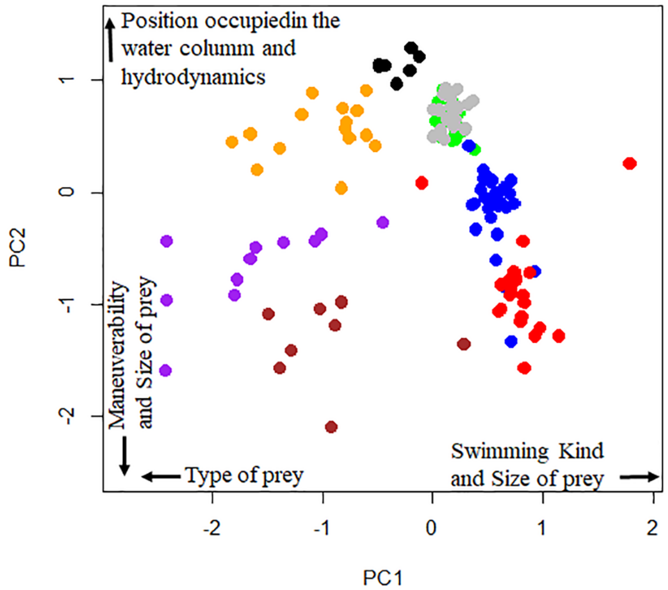

Figure 4. Bi-plot with the two first principal components of the PCA developed using the ecomorphological attributes of the eight species, where: ● *Rhaphiodon vulpinus*, ● *Hydrolycus scomberoides*, ● *Serrasalmus rhombeus*, ● *Pygocentrus nattereri*, ● *Acestrorhynchus falcirostris*, ● *Hoplias malabaricus*, ● *Plagioscion squamosissimus* and ● *Cichla monoculus*.

The Partial Mantel test did not uncover any correlation between the distance matrixes based on feeding items and ecomorphological attributes (r = -0.036; P = 0.572, using 999 permutations), when controlling for the phylogenetic effect.

Discussion

The eight species addressed in this study showed distinct ecomorphogical characteristics, indicating a potential use of different food resources. Nevertheless, no correlation between morphology and diet was found. The index of food importance discriminated these species into two groups: a first one, composed of piscivorous species: *A. falcirostris*, *H. malabaricus*, *R. vulpinus*, *S. rhombeus*, and *P. nattereri*; and, a second one comprising carnivores with a high preference for shrimp: *C. monoculus*, *P. squamosissimus*, and *H. scomberoides.* Of the piscivorous species, the piranha *P. nattereri* displayed dietary preferences different than those expected, and included significant quantities of vegetative material in its diet. In general, piranhas can and did display a broad spectrum of feeding behavior (e.g., Leão et al. 1991). In some cases, *P. nattereri* has been classified as a highly specialized piscivore due its phenotypic characteristics, but retains an ability to explore other feeding resources available in the environment (Piorski et al. 2005, Prudente et al. 2016). Both piranha species have short and laterally compressed bodies and strong anal fins, which are morphological characteristics associated with high maneuverability (Werner 1977, Breda et al. 2005). This maneuverability is particularly well-suited for complex habitats of low speed current (Werner 1977, Webb et al. 1996, Oliveira et al. 2010) such as those found in the flooded areas of Amazonian floodplains.

The other species were typically piscivorous, but likely varied greatly in their methods of ingestion. In general, *R. vulpinus* and *H. scomberoides* are able to eat whole prey due their large mouth with underslung jaw (Howes 1976, Beaumord 1991), but have also been shown to capture their prey using their long canine teeth (Howes 1976).

Due to their large and upward-oriented mouths, these species focus prey-capture at the water surface or at the limnetic zone (Almeida et al. 1997, Saint-Paul et al. 2000). A similarly uniquely adapted species is that of *A. falcirostris.* These fish have highly hydrodynamic bodies and are able to reach high swimming speeds to capture their prey (Webb 1984, Breda et al. 2005), focusing primarily in the pelagic areas (Werner 1977).

The second group includes shrimp-eaters, such as *P. squamosissimus,* which eats shrimp during the season of its high abundance (Merona & Rankin-de-Merona 2004, Costa et al. 2016). These fish change their diet to a focus on fish and insects when shrimp availability declines (Hahn et al. 1997). There is some controversy about the diet of *C. monoculus*. While some researchers propose that this species is a highly specialized piscivore (Rabelo & Araújo-Lima 2002, Mérona & Rankin-de-Mérona 2004), others contest that its diet is focused on shrimp (Teixeira & Bennemann 2007). Our ecomorphological analysis suggests that both feeding strategies may be occurring, but that the strategy employed may change due to seasonal conditions, which could be tested in future studies. Given their morphologies, both *P. squamosissimus* and *C. monoculus* are efficient swimmers and are capable of expanding their mouths to ingest entire prey (Rodrigues & Menin 2006, Teixeira & Bennemann 2007). These characteristics allow these species to exploit the most accessible and abundant feeding items, which could change seasonally from fish to shrimp, insects, among others (Merona & Rankin-de-Mérona 2004, Prudente et al. 2016).

The ecomorphological attributes-based analyses also discriminates groups, but this discrimination does not exhibit a clear relationship with diet, and thus suggests that fish assemblages are more influenced by spatial structure than by trophic structure (Silva-Camacho et al. 2014). Previously published studies in this area exploring the relationship between fish morphology and diet have also proven inconclusive (Felley 1984, Douglas & Matthews 1992, Teixeira & Bennemann 2007). While some studies found close associations (Sampaio et al. 2013, Prado et al. 2016), others found no relationship (Felley 1984, Motta et al. 1995, Silva-Camacho et al. 2014). Conceptually, it could be assumed that when a relationship between morphology and diet is observed, the fish assemblage is ecomorphologically structured (Douglas & Matthews 1992, Breda et al. 2005, Oliveira et al. 2010). In these circumstances, it should be possible to predict resource use based on animal morphology (Gatz Jr. 1979, Watson & Balon 1984, Winemiller 1991, Oliveira et al. 2010). In the absence of such a relationship, the morphological structure could be defined by phylogenetic relationships (Oliveira et al., 2010).

The phylogenetic effect was controlled in this study by applying the Partial Mantel Test and seems not to be a key driver of the ecomorphological discrepancies observed here. Although not addressed by the current study, an alternative hypothesis to be tested in the future to explain this absence of correlation between morphology and diet could be that that these factors are more closely associated with prey availability (e.g., Hugueny & Pouilly 1999). This is a more plausible explanation, as that study was conducted on species within the same trophic guild and our study included only carnivorous fish. Nevertheless, this result could also originate from the difficulty inherent in identifying digested prey. In general, the identification was made only to the level of upper taxonomic groups (e.g., fish, insect, and shrimp) on which high niche overlapping is observed.

Given the absence of a close relationship between diet and morphology, we propose that prey capture by predator fish in Amazonian floodplains is mainly a process driven by the opportunistic behavior of the predator coupled with food availability, as observed by Dias et al. (2017). These opportunistic behaviors could be associated with predator traits such as hydrodynamics, maneuverability, and the position in the water column where the fish preferentially live, which are all related to their morphology.

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Author Contributions

Diogo Campos Cardoso - Contribution to in the concept and design of the study; data collection; data analysis and interpretation; manuscript preparation.

Pieter deHart - Contribution to data analysis and interpretation, critical revision, adding intelectual content.

Carlos Edwar de Carvalho Freitas - Contribution in the concept and design of the study; data analysis and interpretation; critical revision, adding intelectual content.

Flávia Kelly Siqueira-Souza - Contribution in the concept and design of the study; to data analysis and interpretation; to manuscript preparation; adding intelectual content.

Conflicts of interest

The author(s) declare(s) that they have no conflict of interest related to the publication of this manuscript.

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Inventory

Fish fauna of the Pelotas River, Upper Uruguay River, southern Brazil

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Abstract: The fish fauna of the Pelotas River, in the Upper Uruguay ecoregion of southern Brazil was inventoried. Samplings were performed quarterly between August 2013 and May 2014 at 14 sites in the Pelotas River and its tributaries, using gill nets of different mesh sizes, sein nets, cast nets and electrofishing. In total, 7,745 specimens were recorded, comprising 46 species, belonging to 13 families and five orders. Approximately 80% of the species belonged to the orders Characiformes and Siluriformes, as well as the families Characidae and Loricariidae, which included a greater number of species. Of the total species, 24% were endemic to the Upper Uruguay River, four were identified only at the genus level and none was considered non-native. Approximately, half of the 98 species previously recorded for the Upper Uruguay basin were also detected in this study. The tributaries of the Pelotas River exhibited different faunas with five exclusive species. Thirty species were present in both the tributaries and the main channel. In addition, higher species richness, as well as the presence of larger-sized species were observed in the main channel. Many of the species not restricted to the Upper Uruguay River have already been reported as part of the Taquari-Antas River fauna. However, the local biodiversity of this region is under several threats, such as land use and installation of small hydroelectric plants. These results highlight the importance of the conservation of plateau/upland rivers, especially in the Upper Uruguay ecoregion, which shows a peculiar fish fauna and endemism.
Keywords: *Freshwater, upland river, ichthyofauna, inventory, species richness.*

Fauna de peixes do rio Pelotas, Alto rio Uruguai, sul do Brasil

Resumo: A fauna de peixes do rio Pelotas, bacia do Alto Uruguai foi inventariada. As amostragens foram realizadas trimestralmente entre agosto de 2013 e maio de 2014, em 14 pontos da bacia do rio Pelotas, utilizando-se redes de emalhar de diferentes tamanhos, redes de arrasto, tarrafas e pesca elétrica. No total, foram registrados 7.745 exemplares, compreendendo 46 espécies pertencentes a 13 famílias e cinco ordens. Aproximadamente 80% das espécies foram pertencentes as ordens Characiformes e Siluriformes, assim como as famílias Characidae e Loricariidae, que tiveram maior número de espécies. Do total de espécies amostradas, 24% são endêmicas do Alto rio Uruguai, quatro foram identificadas apenas em nível de gênero e nenhuma foi considerada não nativa. Aproximadamente metade das 98 espécies anteriormente registradas na bacia do Alto rio Uruguai foi registrada nesse estudo. Os tributários do rio Pelotas exibiram distinta fauna com cinco espécies exclusivas. Trinta espécies foram comuns aos afluentes e canal principal. Verificou-se maior riqueza, bem como a presença de espécies de maior porte no canal principal. Muitas das espécies não restritas ao alto rio Uruguai já foram relatadas como parte da fauna da bacia do rio Taquari-Antas. No entanto, a biodiversidade local da região de estudo está sob diversas ameaças, como o uso do solo e a instalação de pequenas centrais hidrelétricas. Esses resultados destacam a importância da preservação dos rios de planalto, especialmente na ecorregião do Alto rio Uruguai, que apresenta uma fauna de peixes peculiar e endemismos.
Palavras-chave: *Água doce, rio de planalto, ictiofauna, inventário, riqueza de espécies.*

Introduction

The Pelotas River originates in the Serra Geral Formation, on the border between the states of Santa Catarina and Rio Grande do Sul, southern Brazil, and, along with the Canoas River forms the Uruguay River. In this region, due to the geomorphological characteristics of the Serra Geral Formation, there is a considerable slope, where the river flows over steep and rocky terrain marked by narrow channels with rapids and falls (Feow 2018). The tributaries of this river are generally short and also disrupted by waterfalls (Zaniboni-Filho & Schulz 2003). The climate of the ecoregion is characterized by rainfall well distributed throughout the year (humid subtropical – Cfa) (Köppen 1936), unlike that of other ecoregions of the La Plata basin, and also marked by the absence of flood pulse, floodplains and marginal lakes. These characteristics are strong environmental filters in the selection of species, which, together with other biogeographic factors, favor a peculiar fauna.

Bertaco et al. (2016) recorded 275 fish species from the Uruguay River, of which 78 (28%) are endemic and 25 (9%) are undescribed. Other studies highlighted the high endemism observed in the Araucária Plateau (750 m a.s.l.). Approximately 46% of the species found in the tributaries of the Upper Uruguay River exhibited some degree of endemism. Among these, 16.7%, present high endemism, occurring only in Campos de Cima da Serra (Malabarba et al. 2009). The highest species richness was observed in the drainage of the Pelotas and the Canoas rivers (Uruguay River basin- 60 species), compared to the basins of the Caí and the Taquari-Antas rivers (Jacuí River basin- 46 species). Despite this richness, the geomorphology of the Pelotas River basin makes it a target of incentive programs to install small hydroelectric plants (SHPs). The increase in the construction of hydroelectric dams and agro-industrial activities has implications for the biodiversity, affecting different trophic levels of fish assemblages (Becker et al. 2013, Jorgensen et al. 2013, Schork & Zaniboni-Filho 2017).

Some regions of southern Brazil have been poorly explored, mainly due to the lack of funding, or economic interest and possibly also to the difficulty of access to mountain river. This lack of data is a major drawback for the isolated regions with high endemism. Inventories have been carried out in adjacent ecoregions of the Upper Uruguay River, where is located the Pelotas River, such as the Iguaçu River basin (Abilhoa et al. 2008, Baumgartner et al. 2012, Frota et al. 2016, Larentis et al. 2016, Delariva et al. 2018), Taquari-Antas basin (Becker et al. 2013). Other studies have investigated the fish fauna after the construction of hydroelectric plants in the Uruguay River (Schork & Zaniboni-Filho 2017). However, there is little information specifically on the headwaters of the Pelotas River. Neves et al. (2018) evaluated the trophic guilds at six sites on the main channel of the Pelotas River. Notwithstanding inventories of the fish fauna of the tributaries of the Pelotas River in the same region were not contemplated. Thus, we emphasize that the present contribution is an updated version of this list, including tributaries of the Pelotas River with the use of electric fishing, which increases the probability of sampling small-sized and restricted species. Along with this concern, there are six hydroelectric plants currently installed in the Upper Uruguay region, three of them in the Uruguay River and three in its tributaries (Pelotas, Canoas, and Passo Fundo). In addition to hydroelectric dams, overfishing and industrial waste from pulp and paper mills are additional threats to the Upper Uruguay River basin (Reis et al. 2003).

This inventory presents the checklist of the fish fauna of the Pelotas River and its tributaries. The sampling design of this study, covering 14 sites, allowed us to determine the composition and species richness in this region and discusses the similarities among the local fish fauna in relation to adjacent drainage basins of the Taquari-Antas River. In addition, this inventory provides valuable information about the threat status of the fish fauna especially with a view to the installation of dams and SHPs already planned for this region.

Material and Methods

1. *Study area*

The Pelotas River rises in Serra Geral 64 km from the Atlantic Ocean and has an area of approximately 35,813 Km^2. It has a high slope, with an elevation ranging from 1,600 m to 840 m (Kröhling et al. 2011). The Pelotas River stands out for its ecological importance, agro-industrial activities, and hydroelectric potential.

In this region, the climate is classified as subtropical with rainfall events throughout the year, but with significant amplitude (Strassburger 2005). The vegetation of the region is composed of meadow areas that usually occur at altitudes above 800 m and of the Mixed Ombrophilous Forest, which occupies almost half of the basin and includes two formations: Mountain Forest (500 and 1000 m altitudes) and High Mountain Forest (1000 m altitudes) (Vieira 1984, Strassburger 2005).

2. *Data collection*

Samples were taken quarterly between August 2013 and May 2014 (August, November, February and May) at 14 sampling sites (Figure 1), eight in the channel of the Pelotas River (C01 to C08) and six tributaries (T01 to T06) (Figure 2, Table 1). Fishing gears consisted of gill nets (mesh sizes of 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, and 12.0 cm between opposite knots) and trammel nets (inner mesh sizes of 6, 7 and 8 cm between opposite knots), with lengths of 20 m (Pelotas River) and 10 m (tributaries), installed at 16:00 h and inspected at 22:00 h and 08:00 h, remaining exposed for approximately 16 hours. Cast nets with 2.5, 3.0, 4.0, and 6.0 cm between opposite knots and 15 m diameter were operated during daytime, each net being thrown for 15 min. In the littoral region, seine nets of 10 m length, 2 m depth, and 5 mm mesh size were operated during twilight at each sampling site. At sites T02 and T05, due to their size and depth, only electrofishing was performed in 50 m stretches (three consecutive passes in the mouth-headwaters direction). After capture, fish were anesthetized, fixed in 10% formaldehyde and preserved in 70% alcohol. Fish were collected under license from Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) (process numbers 1372, 1373, 1374 and 1376/2012). This study was conducted in accordance with the protocols in their ethical and methodological aspects, for the use of fish, approved by the Ethics Committee on Animal Use (CEUA) of the Universidade Estadual do Oeste do Paraná.

Fish were identified in the laboratory following published procedures (Zaniboni-Filho et al. 2004, Ghazzi 2008, Serra et al. 2014) and expert assistance, and then measured (total and standard length in cm) and weighed (g). Voucher specimens were deposited at the fish collection of Gerpel (Grupo de Pesquisas em Recursos Pesqueiros e Limnologia, Universidade Estadual do Oeste do Paraná) and the fish

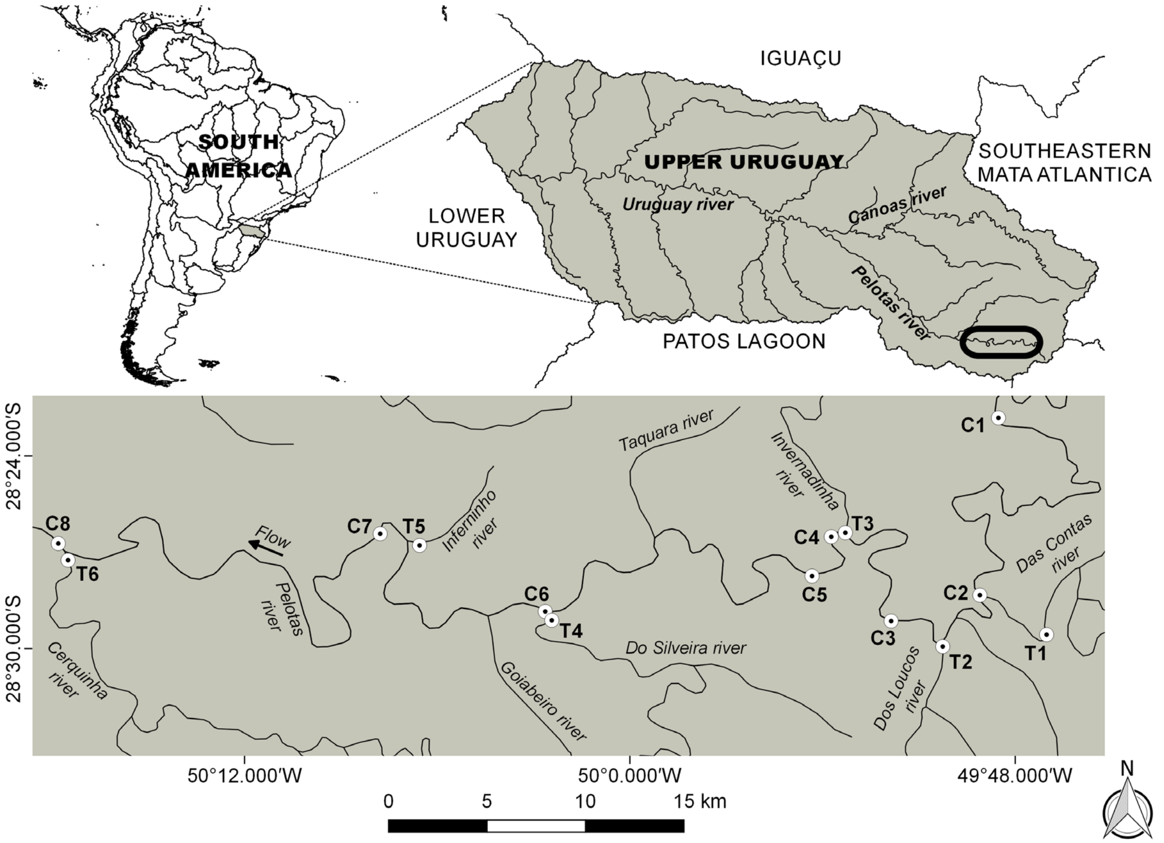

Figure 1. Study area in context of Freshwater Ecoregions of the World (modified from http://www.feow.org/) (Feow 2018). Sampling sites: main channel=C and tributaries (T), Upper Uruguay ecoregion, Brazil.

collection of Nupelia (Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura, Universidade Estadual de Maringá).

Fish were categorized based on their distribution, as endemic (species with distribution restricted to the Upper Uruguay basin) or native (species indigenous from the Uruguay River basin, but not restricted to it) (Zaniboni-Filho et al. 2004, Ghazzi 2008, Becker et al. 2013, Bertaco et al. 2016, Schork & Zaniboni-Filho 2017, Froese & Pauly 2018). In addition, the species composition was compared with that of previous inventories carried out at the Taquari-Antas adjacent basin (Becker et al. 2013, Bertaco et al. 2016) (Table 2). Also added was the threat status of species registered according to the Brazilian Red List of Threatened Species (ICMBio 2018).

Results

A total of 7,745 specimens were recorded, comprising 46 species, belonging to 13 families and five orders (Table 2). The most species-rich orders were Characiformes (45.7%), followed by Siluriformes (34.8 %) and Cichliformes (15.2%). Gymnotiformes and Atheriniformes had only one species each (Figure 3). Characidae was the most representative family (11 species; 23.9%), followed by Loricariidae (nine species; 19.5%) and Cichlidae (eight species; 17.3%) (Figure 4). The other 10 families were responsible for 40% of the species. Four were identified only up to the genus level (*Hyphessobrycon* sp., *Imparfinis* sp., *Odontesthes* sp., *Trichomycterus* sp.) (Figure 5) and none was considered non-native.

In general, higher species richness was recorded in sites located in the main channel. The C02 recorded the highest richness (28 species), followed by C06 (26 species). The lowest richness in the main channel of the Pelotas River was observed at site C01, with only 15 species. Tributaries had richness ranging from 8 species in T05 to 23 species in T01. The fish fauna was characterized by small-sized species, considering that approximately 50% had a standard length lower than 150 mm (Table 2) and occurred in both the main channel and the tributaries. Only seven species (15%) were considered large-sized: 3 of them (*Hoplias australis*, *H. lacerdae* and *Rhamdia quelen*) occurred in both the main channel and the tributaries; while the remaining 4 species (*Schizodon nasutus*, *H.* aff. *malabaricus*, *Hypostomus commersoni* and *H. luteus*) occurred only in the main channel of the Pelotas River.

The most frequent species were *Astyanax dissensus*, *Astyanax xiru*, *Bryconamericus patriciae*, *Oligosarcus brevioris*, *Rhamdia quelen*, and *Crenicichla igara*, all of which were found in all sites. Distinct fish fauna was observed at the different environments, given that five species (*Cheirodon* cf. *interruptus*, *Crenicichla empheres*, *Heptapterus mustelinus*, *Trichomycterus* sp. and *Imparfinis* sp.) occurred only at the tributaries. Except for *C. empheres*, the other species are small-sized. Eleven species, including some medium- and large-sized ones, occurred exclusively in the main channel (Table 2).

Regarding the origin of the species, 11 (24%) are endemic to the Upper Uruguay River basin (Figure 5) and none registered as non-native (Table 2). Of the nearby drainages with available inventories, the only one sharing most of the species with the Pelotas River is the Taquari-Antas River basin (17 species) (Table 2).

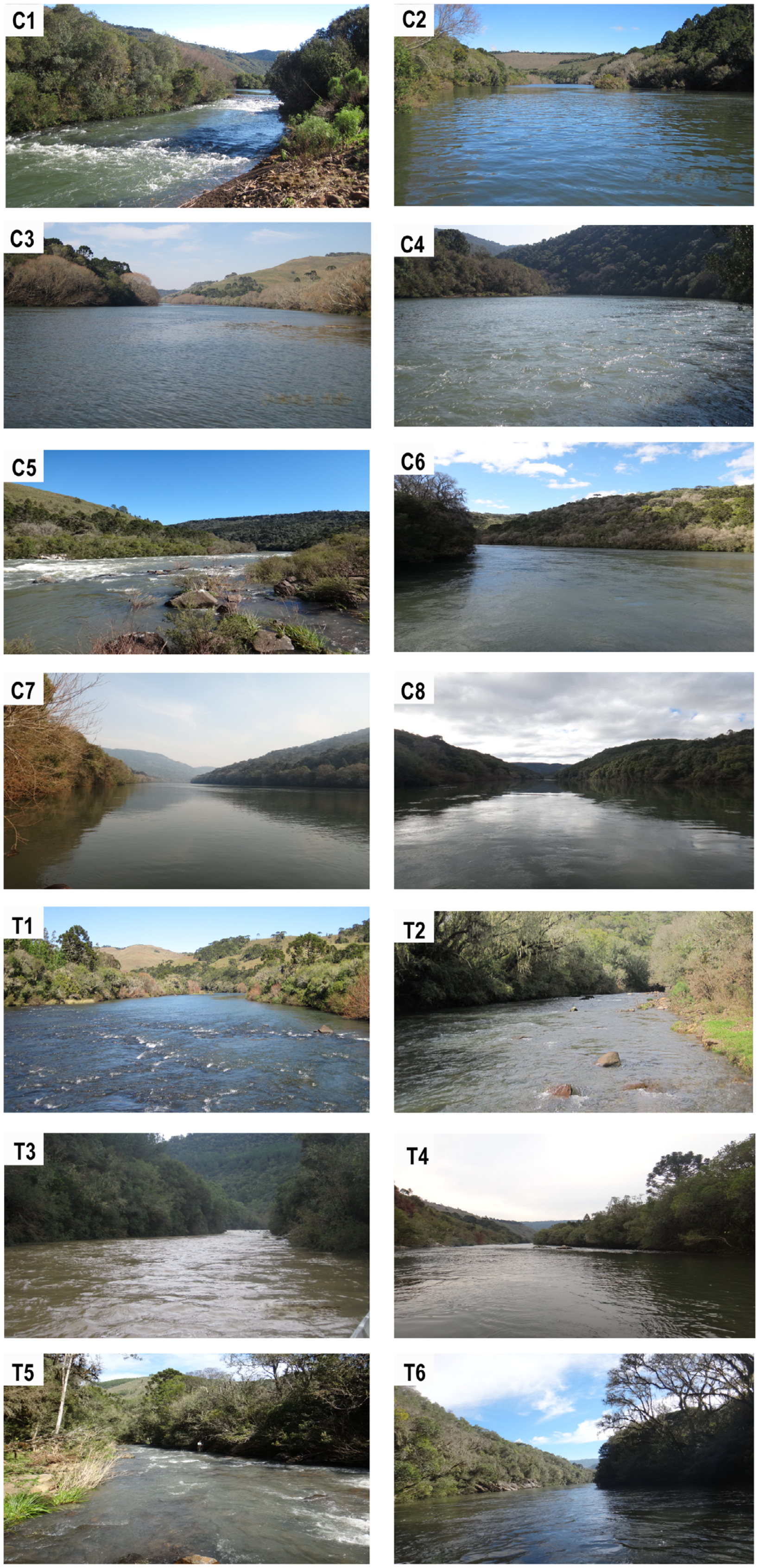

Figure 2. Reaches sampled in the tributaries (T) and main channel (C) of the Pelotas River, Upper Uruguay ecoregion, Brazil.

Table 1. Characteristics of the sampled sites in the Pelotas River basin, Upper Uruguay, Brazil.

Sites	River	Latitude/Longitude	Altitude (m)	river width (m)	flow	river bank	adjacent areas
C01	Pelotas	28º22'49"S/49º48'31"W	1089	35	Rapid waters and backwaters	Both banks ≈10m forested	Extensive cattle raising, agriculture and apple cultivation
C02	Pelotas	28º28'19"S/49º48'60"W	980	60	Rapid Waters and deep wells	Right bank more than 50m and left bank ≈ 10m forested	Extensive cattle raising
C03	Pelotas	28º29'20"S/49º51'57"W	956	80	Rapid Waters and deep wells	Right bank well preserved e left bank ≈ 10m forested	Extensive cattle raising
C04	Pelotas	28º26'25"S/49º53'25"W	939	70	Rapid Waters	Both banks well preserved	Forest area, with little apple culture and pasture areas
C05	Pelotas	28°27'28.53"S/49°55'8.9"W	926	60	Rapid Waters and backwaters	Right banks ≈ 20m and left banks more than 50m	Intensive agriculture and extensive cattle raising
C06	Pelotas	28°28'46"S/50°02'36"W	867	100	Moderate flow	Right banks well preserved and left banks ≈ 10m forested	Preserved, with presence of pasture
C07	Pelotas	28º29'20"S/49º51'57"W	850	150	Moderate flow and backwaters	Right banks ≈ 20m forested. Left banks well preserved	Preserved, with presence of pasture
C08	Pelotas	28°26'43.8"S/50°17'48.4"W	782	100	Rapid Waters and backwaters	Both banks with more than 50m forested	Livestock and diverse family culture
T01	Arroio das Contas	28º29'36"S/49º46'57"W	990	55	Rapid Waters and backwaters	Both banks with more than 50m forested	Extensive areas of apple culture, cattle raising and livestock family culture
T02	Arroio do Louco	28º29'50"S/49º50'19"W	966	15	Rapid Waters	Right banks preserved and left banks unpreserved less than 10m	Extensive cattle raising and livestock family culture
T03	Arroio Invernadinha	28º26'28"S/49º53'16"W	939	30	Rapid Waters and backwaters	Right banks preserved and left banks unpreserved less than 10m	Apple culture, cattle raising and livestock family culture
T04	Arroio Silveira	28°29'10"S/50°02'24"W	899	15	Rapid Waters	Both banks well preserved	Preserved, with little pasture.
T05	Arroio Sem Nome	28°26'38.22"S/50°6'30.3"W	855	6	Shallow rapid waters	Preserved, but with presence of apple culture	Preserved, with little apple and pasture areas.
T06	Arroio Cerquinha	28°27'11.6"S/50°17'38.6"W	787	30	Rapid Waters	Preserved, but with presence of pasture	Preserved, with little pasture

Table 2. Fish species recorded and their respective occurrences at sampling sites in the Pelotas River basin, Upper Uruguay ecoregion, Brazil. The classification of fishes followed Betancur et al. (2013) and species name update according to Fricke et al. (2019). Abundance in numerical percentage (%N) and biomass (%B) and SL= standard lengths (minimum – maximum; cm). The column "Origin" refers to species classified in endemic (EN) and native (NA) to the Upper Uruguay River (*=Asterisks represents an inability to categorize the origin because it is an unidentified species). BRD= Brazilian Red List of Threatened Species: VU= Vulnerable; NT= Near Threatened; DD = Data Deficient; LC = Least Concern; NE= Not Evaluated (ICMBio 2018). Size= reported size that the species can reach: Small (S)= fish less than 20 cm; Medium (M)= 20-40 cm and Large (L)= more than 40 cm. T= tributaries; C= main channel Pelotas River. Voucher specimens: individuals deposited in Ichthyology Collection of GERPEL (CIG) and Fish Collection of Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (NUP). Staining in the table indicates the occurrence of the species according to the literature: Becker et al. (2013) for the Taquari-Antas (TqA), Bertaco et al. (2016) involving Uruguay (Uru) and Taquari-Antas/Patos lagoon (TqA).

Taxonomic position/species	%N	%B	SL (cm)	Origin	BRD	Uru	TqA	Size	T01	T02	T03	T04	T05	T06	C01	C02	C03	C04	C05	C06	C07	C08	Voucher specimens
CHARACIFORMES																							
Parodontidae																							
Apareiodon affinis (Steindachner, 1879)	0,1	0,1	9.2 - 11.5	NA	LC	▒		S						x								x	CIG 2270
Curimatidae																							
Steindachnerina biornata (Braga & Azpelicueta, 1987)	10,6	9,7	4.4 - 14.0	NA	LC	▒	▓	S	x		x	x		x		x	x	x	x	x	x	x	CIG 2334
Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)	0,5	0,2	2.0 - 8.6	NA	LC	▒		S														x	CIG 2295
Anostomidae																							
Leporinus amae Godoy, 1980	1,8	2,1	7.4 - 15.7	NA	LC	▒		S	x			x			x	x	x	x	x	x	x		CIG 2285
Schizodon nasutus Kner, 1858	0,0	0,2	27.0	NA	LC	▒		L														x	CIG 2373
Characidae																							
Cheirodon cf. *interruptus* (Jenyns, 1842)	0,1	0,0	3.3 - 4.2	NA	LC	▒	▓	S						x									NUP 16271
Astyanax aff. *fasciatus* (Cuvier, 1819)	0,7	0,4	6.9 - 11.8	NA	LC	▒	▓	S			x			x		x	x		x	x	x	x	CIG 2276
Astyanax dissensus Lucena & Thofehrn, 2013	4,1	0,7	2.3 - 10.2	NA	LC	▒	▓	S	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2265
Astyanax paris Azpelicueta, Almirón & Casciotta, 2002	3,4	1,1	2.7 - 10.1	EN	NE	▒		S	x	x	x	x			x	x	x	x				x	CIG 2276
Astyanax cf. *procerus* Lucena, Castro & Bertaco, 2013	0,1	0,0	6.0 - 6.1	NA	LC		▓	S				x				x							CIG 2288
Astyanax saguazu Casciotta, Almirón & Azpelicueta 2003	9,4	2,8	2.8 - 12.1	NA	LC	▒		S	x	x	x	x		x	x	x	x	x	x	x	x	x	CIG 2271
Astyanax xiru Lucena, Castro & Bertaco, 2013	16,1	10,5	2.4 - 12.9	NA	LC	▒	▓	S	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2267
Bryconamericus patriciae da Silva, 2004	22,6	3,1	2.0 - 8.4	NA	LC	▒	▓	S	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2257
Hyphessobrycon sp.	0,1	0,0	3.6 - 5.2	NA*	NE			S						x			x					x	CIG 2255
Oligosarcus brevioris Menezes, 1987	3,5	9,0	2.2 - 25.6	EN	LC	▒		M	x	x	x	x		x	x	x	x	x	x	x	x	x	CIG 2341
Oligosarcus jenynsii (Günther, 1864)	0,8	2,5	8.0 - 24.7	NA	LC	▒	▓	M	13			x		x	x	x	x	x	x	x	x		CIG 2331

Continuation Table 2.

Taxonomic position/species	**%N**	**%B**	**SL (cm)**	**Origin**	**BRD**	**Uru**	**TqA**	**Size**	**T01**	**T02**	**T03**	**T04**	**T05**	**T06**	**C01**	**C02**	**C03**	**C04**	**C05**	**C06**	**C07**	**C08**	**Voucher specimens**
Acestrorhynchidae																							
Acestrorhynchus pantaneiro Menezes, 1992	0,0	0,0	16.4	NA	LC	▒	▓	M	1													x	CIG 2310
Erythrinidae																							
Hoplias australis Oyakawa & Mattox, 2009	0,1	1,3	26.1 - 29.1	EN	LC	▒		L				x		x		x	x		x				CIG 2368
Hoplias lacerdae Miranda Ribeiro, 1908	0,5	8,1	9.6 - 54.0	NA	LC	▒	▓	L	x							x	x	x	x	x	x	x	CIG 2332
Hoplias aff. *malabaricus* (Bloch, 1794)	0,0	0,2	27.1 - 27.1	NA	LC	▒	▓	L														x	CIG 2365
SILURIFORMES																							
Trichomycteridae																							
Trichomycterus sp.	1,9	0,1	2.7 - 7.7	NA*	NE			S		x			x										NUP 18123
Loricariidae																							
Hemiancistrus fuliginosus Cardoso & Malabarba, 1999	4,2	6,3	5.9 -22.6	NA	LC	▒		S	x		x	x		x	x	x	x	x	x	x	x	x	CIG 2329
Hypostomus commersoni Valenciennes, 1836	0,1	0,5	16.3 -21.3	NA	LC	▒	▓	L										x	x	x		x	CIG 2366
Hypostomus isbrueckeri Reis, Weber & Malabarba, 1990	4,3	16,4	6.5 - 24.9	NA	LC	▒		M	x			x		x		x	x	x	x	x	x	x	CIG 2354
Hypostomus luteus (Godoy, 1980)	0,0	0,1	17.0	EN	LC	▒		L												x			NUP 16848
Pareiorhaphis hystrix (Pereira & Reis, 2002)	2,0	0,1	8.0 - 9.9	NA	LC	▒	▓	S		x			x		x					x			CIG 2333
Rineloricaria anitae Ghazzi, 2008	0,2	0,1	10.2 - 14.4	EN	NE	▒		M								x		x		x	x		CIG 2297
Rineloricaria capitonia Ghazzi, 2008	0,6	0,3	10.1 - 15.3	EN	LC	▒		M	x	x	x				x	x		x	x	x	x		CIG 2299
Rineloricaria reisi Ghazzi, 2008	0,5	0,2	8.7 - 15.3	NA	LC	▒		M	x		x	x			x	x		x					CIG 2324
Rineloricaria tropeira Ghazzi, 2008	0,2	0,1	11.6 - 15.1	EN	LC	▒		M	x							x	x	x					CIG 2298
Heptapteridae																							
Heptapterus mustelinus (Valenciennes, 1835)	1,0	0,5	2.9 - 22.8	NA	LC	▒	▓	S		x			x										CIG 2041
Imparfinis sp.	0,0	0,0	9.7	NA*	NE			S		x													NUP 18133
Rhamdella longiuscula Lucena & da Silva, 1991	2,0	1,9	9.2 - 20.8	NA	LC	▒		M	x	x	x	x		x	x	x	x	x	x	x	x		CIG 2349
Rhamdia quelen (Quoy & Gaimard, 1824)	2,5	10,4	11.1 - 34.2	NA	LC	▒	▓	L	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2369
Pimelodidae																							
Iheringichthys labrosus (Lütken, 1874)	0,1	0,3	14.3 - 20.5	NA	LC	▒		M						x					x		x	x	CIG 2326
Pimelodus maculatus Lacepède, 1803	0,3	3,7	22.9 - 32.0	NA	LC	▒		M	x								x	x	x	x	x	x	CIG 2360

Continuation Table 2.

Taxonomic position/species	%N	%B	SL (cm)	Origin	BRD	Uru	TqA	Size	T01	T02	T03	T04	T05	T06	C01	C02	C03	C04	C05	C06	C07	C08	Voucher specimens
GYMNOTIFORMES																							
Sternopygidae																							
Eigenmannia trilineata López and Castello, 1966	0,0	0,0	30.3	NA	LC			S											x				CIG 3285
ATHERINIFORMES																							
Atherinopsidae																							
Odontesthes sp.	0,6	1,2	2.4 - 26.9	NA*	NE			S	x		x	x		x		x	x	x	x	x			CIG 2360
CICHLIFORMES																							
Cichlidae																							
Australoheros taura Ottoni & Cheffe, 2009	0,1	0,1	7.2 - 9.2	NA	DD		■	S			x					x	x		x				CIG 2246
Crenicichla celidochilus Casciotta, 1987	1,5	1,9	5.8 - 21.1	NA	LC	▒		M	x	x		x		x		x	x	x	x	x	x	x	NUP 18131
Crenicichla empheres Lucena, 2007	0,0	0,0	11.2-12,6	EN	VU	▒		M	x														
Crenicichla igara Lucena & Kullander, 1992	2,6	3,2	5.1 - 19.4	EN	NT	▒		M	x	x	x	x	x	x	x	x	x	x	x	x	x	x	CIG 2279
Crenicichla jurubi Lucena & Kullander, 1992	0,0	0,0	10,5-12,5	EN	NT	▒		M								x							
Crenicichla missioneira Lucena & Kullander, 1992	0,1	0,2	13.1 - 15.6	NA	LC	▒		M								x		x		x			CIG 2307
Crenicichla tendybaguassu Lucena & Kullander, 1992	0,1	0,1	8.1 - 17.0	EN	LC	▒		S								x		x		x			CIG 2254
Geophagus brasiliensis (Quoy & Gaimard, 1824)	0,3	0,3	2.3 - 12.1	NA	LC	▒	■	S									x		x	x		x	CIG 2248
Species richness									23	15	16	19	8	20	15	28	24	25	25	26	20	24	

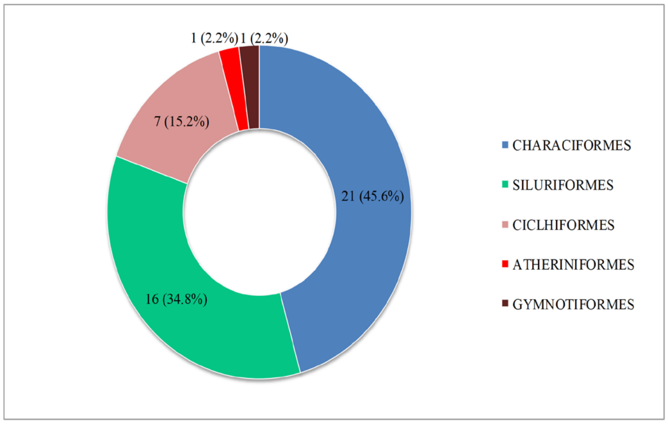

Figure 3. Specific richness to fish orders recorded in Pelotas River basin, Upper Uruguay ecoregion, Brazil. In side numbers represents the absolute and percentage species richness, respectively, to each order.

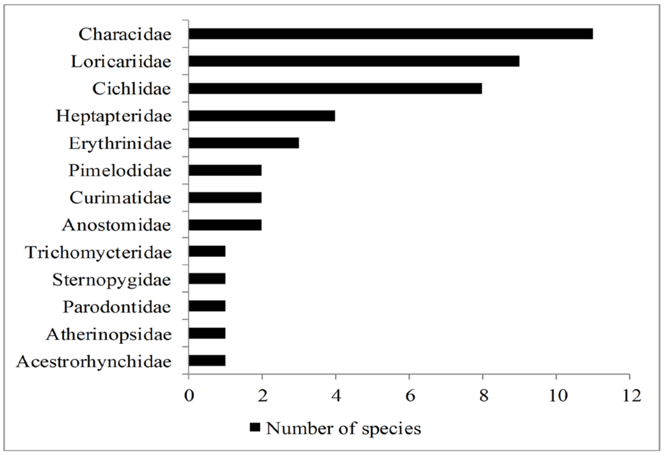

Figure 4. Specific richness to fish families recorded in Pelotas River basin, Upper Uruguay ecoregion, Brazil.

Discussion

The species richness recorded at each sites ranged from 8 to 28, totaling 46 species. This value is almost 50% of the 98 species previously recorded for the Upper Uruguay River (Zaniboni-Filho et al. 2004, Schork & Zaniboni-Filho 2017). The dominance of Characiformes and Siluriformes, corresponding to 82% of the recorded species, was similar to that documented for Neotropical fish fauna in general (Reis et al. 2016). Many previous studies already demonstrated that this dominance occurs not only in the Upper Uruguay (Schork & Zaniboni-Filho 2017), but also at its lower course (Zaniboni-Filho et al. 2004) and in adjacent basins (Becker et al. 2013, Bertaco et al. 2016). The lower richness of Atheriniformes and Gymnotiformes (2.2%) is in line with the findings of Bertaco et al. (2016) in three drainages of the Rio Grande do Sul State. However, it contrasts with reports referred to other Neotropical basins in which Gymnotiformes have greater contribution (Ota et al. 2018).

Characidae, Loricariidae and Cichlidae are the dominating families with approximately 60% of total richness. The proportional composition of species by family found in the study area is similar to that observed in the Taquari-Antas system, in the Patos Lagoon ecoregion (Bertaco et al. 2016). Characidae, with a great number of smaller-sized and generalist species (*sensu* Abelha et al. 2001), is usually co-dominant with Loricariidae (Reis et al. 2016); however, Characidae showed higher richness in the Pelotas River. In this sense, small characids (especially of the genera *Astyanax* and *Bryconamericus*), with compressed bodies and nektonic habit, have the ability to explore all the compartments of the lotic environments. This includes, for example, being successful in rapidly flowing environments, typical of upland rivers, as well as in backwaters. In a similar way, Loricariidae was here represented mainly by two genera, *Rineloricaria* Bleeker (four species described in 2008) and *Hypostomus* Lacépède (three species), which is by far the largest genus of Loricariidae and the second largest genus of catfish (Oyakawa et al. 2005). The dorsally flattened body and the suckermouth present in most Loricariidae provide greater attachment to the substrate and favor the displacement in stretches of rapids (Oliveira et al. 2010).

Cichlidae dominated among the families due to the occurrence of six species of *Crenicichla*, four of them endemic to the Upper Uruguay ecoregion. The Cichlidae family is exceptional among the Actinopterygii in relation to its high rate of phenotypic diversification and is found over most of the tropical and subtropical cis-Andean South America (Lucena & Kullander 1992).

The predominant landscape in the Upper Uruguay is considered of great ecological importance, particularly due to its geomorphological and hydrographic characteristics such as the plateau, with high altitude and slope. Most of the species had small geographic ranges, with more than half restricted to the ecoregion (Bertaco et al. 2016). The sampling sites established in the Pelotas River were essentially constituted by rapids and falls, which have greatly influenced the geographical distribution of the fish fauna. These peculiarities reflected in a fish fauna dominated by species that exhibit favorable performance to explore faster waters, with restricted dispersion. In addition, the presence of large waterfalls contributes to the low occurrence of migratory species, generally restricted to the Uruguay River and lower tributaries (Schork & Zaniboni-Filho 2017).

Physiographic characteristics, water quality, chemical composition of the soil (Albert & Reis 2011), and other environmental filters (Leitão et al. 2018), can affect the occurrence of species and lead to local variations in species richness. These factors may explain the finding that only six species were common to all sampling sites, especially those of the genus *Astyanax*. The wide distribution and abundance of this genus is a common pattern in the Uruguay basin, as well as in other adjacent basins (Baumgartner et al. 2012, Bertaco et al. 2016). In contrast, many species occurred at a single site, for example, *Cheirodon* cf. *interruptus*, and *Imparfinis* sp. (which occurred in the tributaries), and *Acestrorhynchus pantaneiro*, *Eigenmannia trilineata*, *Crenicichla empheres*, *Crenicichla jurubi*, *Schizodon nasutus*, *Steindachnerina brevipinna*, *Hoplias* aff. *malabaricus*, and *Hypostomus luteus* (which occurred in the main channel). It should be noted that, in addition to the 4 species unresolved taxonomy (*i.e.*, are still undescribed) (*Hyphessobrycon* sp., *Imparfinis* sp., *Odontesthes* sp., and *Trichomycterus* sp.), which may be species restricted to the Pelotas river basin, three other species (*Astyanax* cf. *procerus*, *Eigenmannia trilineata*, and *Australoheros taura*) were records not mentioned in previous inventories available for the Upper Uruguay River.

The comparison between the species recorded in the present study and those reported in previous studies performed by Becker et al. (2013) and Bertaco et al. (2016) in the Taquari-Antas basin, allows making some generalizations about the regional fish fauna. The Pelotas

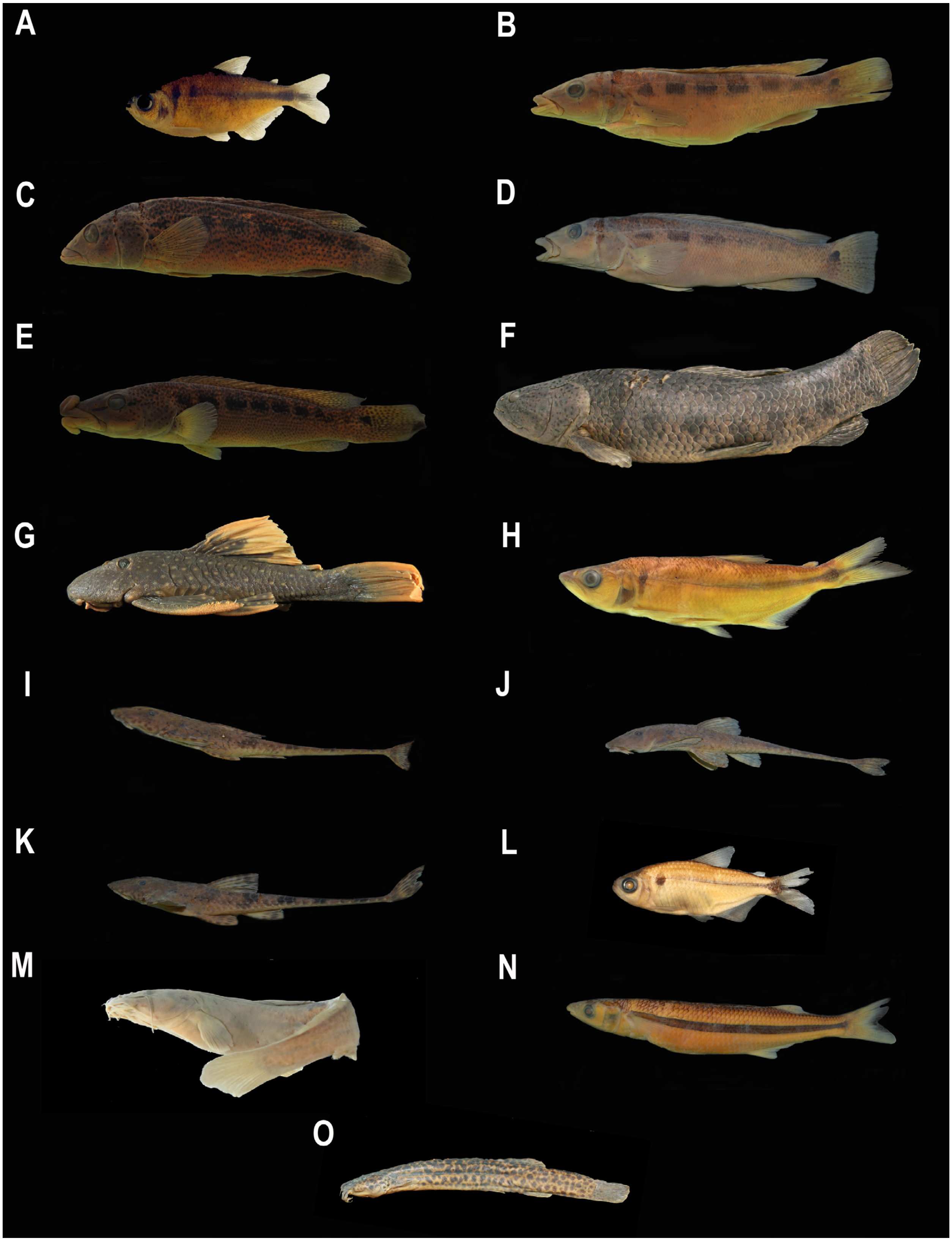

Figure 5. Representative's specimens sampled in the Pelotas River basin that are considered endemic to the Upper Uruguay ecoregion (A-K) and those specimens identified only at the genus level and possibly new species (L-O). The standard length (SL-mm) of the exemplar pictured is presented after the name of species. A) *Astyanax paris* (65 mm); B) *Crenicichla empheres* (110 mm); C) *Crenicichla igara* (125 mm); D) *Crenicichla jurubi* (115 mm); E) *Crenicichla tendybaguassu* (170 mm); F) *Hoplias australis* (257 mm); G) *Hypostomus luteus* (170 mm); H) *Oligosarcus brevioris* (150 mm); I) *Rineloricaria anitae* (120 mm); J) *Rineloricaria capitonia* (133 mm); K) *Rineloricaria tropeira* (116 mm); L) *Hyphessobrycon* sp. (39 mm); M) *Imparfinis* sp. (97 mm); N) *Odontesthes* sp. (147mm); O) *Trichomycterus* sp. (69 mm).

River drainage shares 17 species (36.9%) with the Lagoon of the Patos system. Furthermore, when analyzed in terms of higher taxa (family and genera) as well as aspects of habitat occupation, a peculiar similarity is observed, especially in relation to three factors: i) high endemism within Loricariidae and the genera *Astyanax*; ii) a high number of small-sized species; (iii) absence of long-range migratory species. In this aspect, the composition of species was more similar with inventories conducted in the adjacent basin of the Taquari-Antas River (Becker et al. 2013, Bertaco et al. 2016), than the fauna of lower reaches of the basin of the Uruguay River itself (Zaniboni-Filho et al. 2004, Schork & Zaniboni-Filho 2017). The highest similarity with the Taquari-Antas drainage basin is possibly associated with a greater sharing of headwater streams divided by the tectonic processes that culminated in the emergence of the Serra do Mar (Ribeiro 2006, Reis 2017). Also, natural drainage evolution over geological time includes drainage rearrangement, which severs connections and provides new interdrainage links (Bishop 1995). In this sense, further speculation on the genesis of the sharing of high endemism, but in distinct taxa, could serve as encouragement for future studies of particular interest to evolutionary biology.

According to Bertaco et al. (2016), the species richness knowledge has been always strictly related to collecting efforts. Small-sized species represents an important source of new species, along with regions or unexplored habitats, sometimes associated with restricted distribution of species. Four species identified only at the genus level in this study are considered small-size and are under expert review (*Hyphessobrycon* sp., *Imparfinis* sp., *Odontesthes* sp., *Trichomycterus* sp.). The genus *Hyphessobrycon* has approximately 130 species already described (Carvalho & Langeani, 2013), being polyphyletic and still without taxonomic resolution. In the Uruguay River, 11 species of *Hyphessobrycon* were reported by Betancur et al. (2013) (*H. anisitsi*, *H. bifasciatus*, *H. boulengeri*, *H. eques*, *H. igneus*, *H. isiri*, *H. luetkenii*, *H. meridionalis*, *H. nicolasi*, *H. reticulatus*, *H. togoi*). *Hyphessobrycon* sp. was recorded in samples obtained from the main channel and from tributaries. These specimens differ from the above-mentioned species by at least one of the following characteristics: lack of spots on the dorsal fin and distal region of the anal; presence of longitudinal strips strongly touching the stalk of the peduncle; body shape; humeral spot; number of cusps on teeth; number of rays in the anal fin (hard or branched); number of longitudinal line scales; number of scales above lateral line; and fins bony hooks. The specimens collected from the Pelotas River basin do not have the characters of *Hyphessobrycon* s.s. (sensu, Carvalho & Malabarba, 2015), thereby, further studies are needed, including an osteological analysis, for a final decision about the taxonomic status of these specimens.

Imparfinis sp. presents characteristics divergent from those exhibited by *I. mishky*. In one specimen captured, the adipose fin reaches the caudal fin that is not strongly forked. This specimen is under review by Flávio Bochmann, who is considering the possibility of being in front new species. Specifically in the case of *Odontesthes* sp., it differs from other species occurring in the Uruguay River basin (*O. bonariensis*, *O. perugiae* and *O. yucuman*) by the presence of 21 or less gill rakers on the lower branch (Wingert et al., 2017). In addition, other morphological and osteological features are being investigated to confirm the identity of this species. In relation to *Trichomycterus* sp., the captured specimens from the Pelotas River basin do not resemble the species described for Upper Uruguay River, like *T. perkos* (Datovo et al., 2012), that present different color pattern and to *T. tropeiro* (Ferrer & Malabarba 2011), described for Antas River, that show absence of pelvic fin. On the other hand, *Trichomycterus* sp. is very similar to *T. balios* (Ferrer & Malabarba 2013), a species of the Patos Lagoon system and upper portions of the Mampituba basin. However, because of the small number of specimens captured, they were not diaphanized; this prevented performing osteological evaluations and more accurate comparisons with this species of the neighboring basin. Bertaco et al. (2016) mention the presence of *T. perkos* and several other species not yet described for the Upper Uruguay, and the species observed at the Pelotas River may be one of them. It should be noted, however, that there is still the possibility of being in front of a new and endemic species of the Pelotas River.

The main threats in continental waters are changes in habitats arising from land uses and impoundments (Pelicice et al. 2017) and these are also imminent in the Pelotas River basin (Model et al. 2018). A growing number of hydroelectric projects are being established in the Upper Uruguay River basin in Brazil. Of a total of six large power plants planned for the region, five have already been built (Schork & Zaniboni-Filho 2017). Additionally, the installation of four small hydroelectric plants in the Pelotas River is under planning. Owing to these drastic changes in the local landscape, there is an urgent need to establish measures for the conservation of fish fauna. The impoundments facilitate the dispersion of species that are now endemic to the Pelotas River, or to their local extinction, and also can allow species that are currently absent from the Pelotas River basin to colonize it.

Considering all species registered in this study, according to Brazilian Red List of Threatened Species (ICMBio 2018), one (*C. empheres*) is considered “Vulnerable”, two (*C. igara* and *C. jurubi*) Near Theatened (NT), one (*A. taura*) as Deficient Data (DD), thirty six were classified as Least Concern (LC) and six still Not Evaluated (NE) (Table 2). *C. empheres, C. igara* and *C. jurubi* as well as most species are associated with environments of rapids. In this respect, the scenario of alterations in the Pelotas River will strongly affect a still little-known fauna which is already threatened of global extinction.

In summary, this study is important not only because it describes fish richness, but also because it highlights the enormous challenges to be faced by ichthyologists, that is, to obtain basic knowledge of occurrence and status of conservation of fish fauna in areas of relevant biogeographic importance. Since most of the species reported in this study have restricted distribution, especially those of the genera *Rineloricaria*, *Hypostomu*s and *Crenicichla*, the preservation of lotic stretches is essential to ensure their conservation. In view of the current scenario of fragmentation of the Upper Uruguay basin, our findings highlight the need to establish careful and consistent policies for the conservation and management of an ichthyological area of the paranoplatensean basin that encompasses many endemic species and others possibly still unknown to science.

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Author Contributions

Rosilene Luciana Delariva: Substantial contribution in the concept and design of the study, data analysis, interpretation and manuscript preparation.

Mayara Pereira Neves: Contribution to data analysis, interpretation and manuscript preparation.

Gilmar Baumgartner: Contribution to data collection, to critical revision, adding intellectual content.

Dirceu Baumgartner: Contribution to data collection, to critical revision, adding intellectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Short Communication

Frequency of leucism in a colony of *Anoura geoffroyi* (Chiroptera: Phyllostomidae) roosting in a ferruginous cave in Brazil

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REIS A.S., ZAMPAULO R.A., TALAMONI S.A. **Frequency of leucism in a colony of *Anoura geoffroyi* (Chiroptera: Phyllostomidae) roosting in a ferruginous cave in Brazil**. Biota Neotropica. 19(3): e20180676. http://dx.doi.org/10.1590/1676-0611-BN-2018-0676

Abstract: We provide the first report of the frequency of leucism for a species of Neotropical bat. Leucism is an anomaly of the skin pigmentation of an animal that manifests itself as the total or partial loss of the natural color of the species, and can affect part of or the entire body. During a study involving capture and marking individuals of a population of *A. geoffroyi* residing in a cave in the Brazilian state of Minas Gerais, seven individuals with some degree of depigmentation were recorded out of 616 individuals marked, for a frequency of 1.1%. Since leucism is due to recessive gene expression, these findings may indicate that the population is isolated and possesses a high level of endogamy. Factors that may be responsible for this condition in the studied population remain unknown.
Keywords: *Glossophaginae, hypopigmentation, bats, Iron Quadrangle.*

Frequência de leucismo em uma colônia de *Anoura geoffroyi* (Chiroptera: Phyllostomidae) abrigada em uma caverna ferruginosa no Brasil

Resumo: Relatamos aqui o primeiro registro de frequência de leucismo em uma espécie de morcego Neotropical. Leucismo é uma anomalia na pigmentação da pele dos animais que consiste na perda total ou parcial da cor natural da espécie, podendo acometer partes ou todo o corpo do animal. Em um estudo de captura e marcação de indivíduos de uma população de *A. geoffroyi* abrigada em uma caverna localizada no estado de Minas Gerais, foram registrados sete indivíduos com algum grau de despigmentação dentre 616 indivíduos marcados, representando 1.1% da população. Leucismo é um tipo de anomalia de coloração de expressão gênica recessiva, portanto, esse resultado pode indicar isolamento da população e nível elevado de endogamia. Fatores que podem levar à esta condição nessa população são desconhecidos.
Palavras-chave: *Glossophaginae, hipopigmentação, morcegos, Quadrilátero Ferrífero.*

Introduction

Leucism is an anomaly of the pigmentation of the skin of animals and manifests itself as the total or partial loss of the natural color of the species, and can affect parts of or the entire body of an individual (Miller 2005; Acevedo & Aguayo 2008). Differing from albinism, in which individuals have red eyes due to the total lack of pigmentation, leucistic individuals retain their normal eye color but exhibit hypopigmentation in the pelage, which can be partial or total (Fertl & Rosel 2002; Marín-Vasquez et al. 2010; Abreu et al. 2013).

The occurrence of pigmentation anomalies in wild populations is apparently rare (Walter 1914; Sánchez-Hernández et al. 2010; Talamoni et al. 2017). The low frequency of these phenotypes is attributed to the higher susceptibility of these animals to predation (Sazima & Di-Bernardo 1991; Parsons & Bonderup-Nielsen 1995). According to Walter (1938), only one in every 20,000 individuals has some form of albinism. Pigmentation abnormalities have been recorded in fish, reptiles, birds and mammals (Uieda 2000, Abreu et al. 2013); such abnormalities occur more frequently in small and isolated populations due to inbreeding, which increases the likelihood that recessive alleles are expressed (Bensch et al. 2000).

There have been several recent reports of leucism for phyllostomid bats (Boada & Tirira 2010; Marín-Vasquez et al. 2010; Medina & López 2010; Sánchez-Hernández et al. 2010; García-Morales et al. 2012; López-Wilchis & Galván 2012; Rocha et al. 2013; Treitler et al. 2013; Brito & Leon 2014; Trujillo & Barahona 2014; Biassi et al. 2017), molossid bats (Caire & Thies 1988; Barquez et al. 2003; Geiger & Pacheco 2006), and vespertilionid bats (Barquez et al. 2003; Idoeta et al. 2011). Nonetheless, even though microchiropterans represent a group with the second greatest number of reported cases of leucism among Neotropical mammals (Abreu et al. 2013), there remains a lack of studies addressing the factors related to its occurrence in bats.

Complete depigmentation of the skin, or albinism, in *Anoura geoffroyi* (Gray, 1838) has been reported in Trinidad and Tobago in the southern Caribbean, where a young individual was observed inside a cave (Hargreaves 2013). Although, in this case, the author does not present population data or number of individuals collected. Herein, we provide the first report of the frequency of partial hypopigmentation for a bat colony, using a small cave in an iron formation in the Quadrilátero Ferrífero (Iron Quadrangle) in Southeast Brazil as a diurnal roost, which was be monitored with the mark-recapture method.

Material and Methods

The studied colony utilizes the cave MJ-05 (WGS 84 - 20° 5'40.27"S and 44° 4'36.07"W - 1.072m a.s.l), located in the municipality of Brumadinho, in the metropolitan area of Belo Horizonte, state of Minas Gerais, Brazil (Figure 1). The municipality of Brumadinho is located in the Quadrilátero Ferrífero (Iron Quadrangle), which is considered one of the most important mineral provinces in the country mainly due to its gold and iron deposits (Dorr 1969). The climate of the region is of the Cwb type, and classified as subtropical at altitude, with dry winters and rainy summers (Ribas 2010). The municipality is located in a region dominated by semideciduous seasonal forests, high-montane fields and campos rupestres (rupestrian grasslands) (Markus 2003).

Captures were performed only in the cave MJ-05 between March 2017 and February 2018, during monthly daytime visits to the roost that lasted 8 hours each for a total of 12 field days and 96 hours of captures. Bats were captured using a 2-m long retractable rod. The captured bats were marked with an aluminum band coupled to a necklace. The bands were sequentially numbered with the number preceded by AR to facilitate the identification of individuals in the case of recapture. The captured individuals were weighed, measured, marked and released.

All of the procedures performed during the work were authorized by Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) issued by SISBio (#55700/2). The handling of the animals was also licensed by the Comissão de Ética no Uso de Animais (#019/2016). Voucher material was deposited in the reference collection of the mastozoology laboratory of Pontifícia Universidade Católica de Minas Gerais.

Results and Discussion

A total of 616 individuals of *Anoura geoffroyi* were captured, of which seven individuals exhibited patches of hypopigmentation characteristic of leucism, representing 1.1% of the population. The leucistic individuals were captured in April, June, July, September,

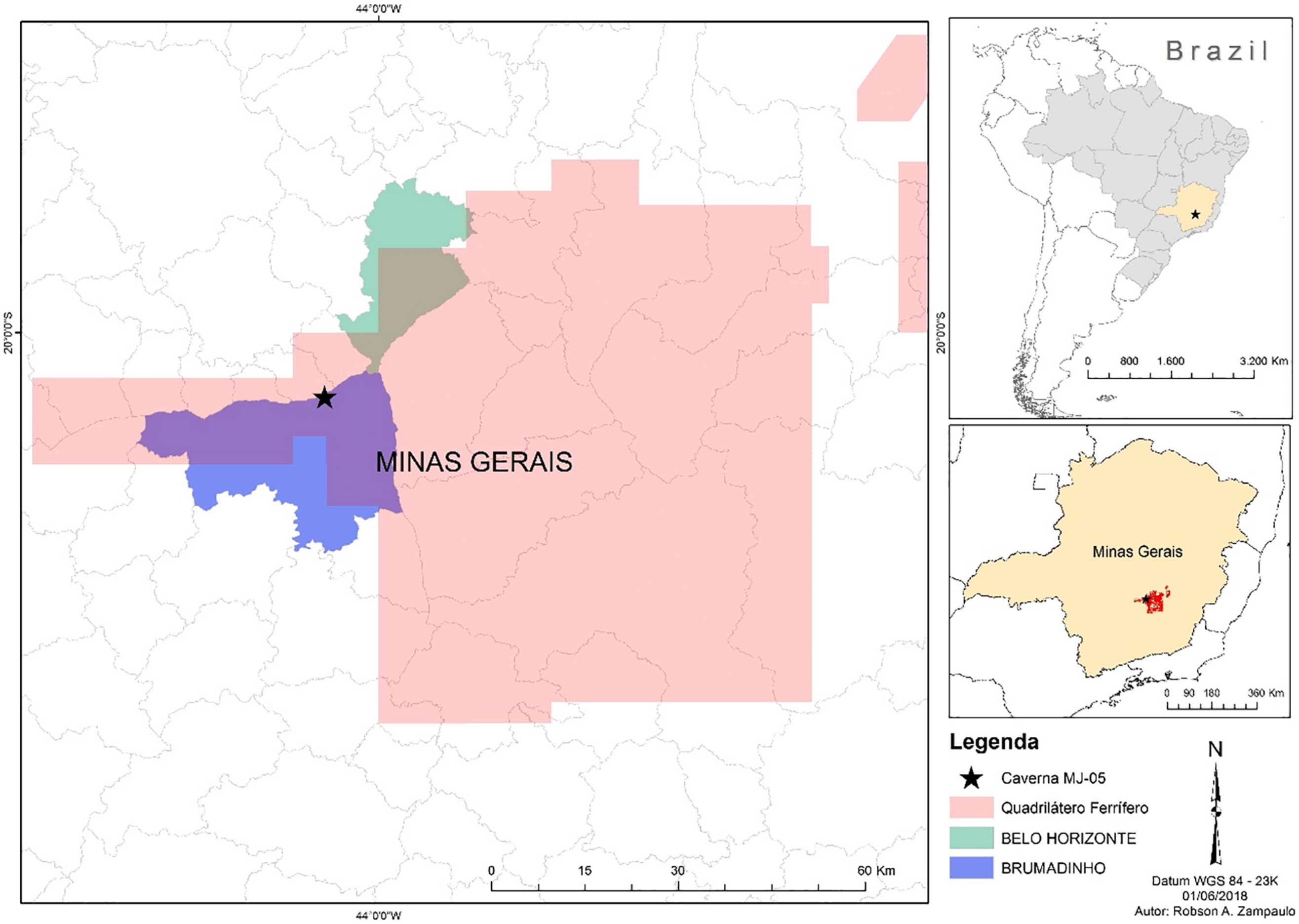

Figure 1. Location of cave MJ-05 in the municipality of Brumadinho, state of Minas Gerais, Brazil. The Quadrilátero Ferrífero (Iron Quadrangle) is shown in pink.

October and November and comprised four males and three females (Table 1). These bats were examined, marked and had their patches photographed, and then were released in the cave, with the exception of the individual that was sacrificed and kept as a voucher specimen (MZ694).

The leucistic individual AR076 had depigmentation on the patagium between metacarpals III and V (Figure 2A); the individual AR121 had greater depigmentation at the base of the right ear, tragus and rostrum (Figure 2B). The voucher specimen had more evident depigmentation, encompassing both ears, a region on both forearms and in the plagiopatagium near the body (Figure 2C and D). The individuals AR205, AR300, AR323 (Figure 2E) and AR361 exhibited depigmentation of parts of the patagium and the extremity of the wing. Among these individuals, AR300 possessed many spots of depigmentation, with several small white spots on both wings (Figure 2F).

This is the first case of leucism formally reported for this species in Brazil. Reports of hypopigmentation in bats are usually sporadic, and are usually obtained by chance during chiropteran surveys (Geiser & Pacheco 2006; Rocha et al. 2013; Biassi et al. 2017).

Under normal conditions, albino mammals are negatively selected because they are more visible to predators (Parsons & Bondrup-Nielsen 1995). The greater vulnerability of albino animals to predation (Parsons & Bondrup-Nielsen 1995; Uieda 2000) can be extrapolated, to some degree, to other types of hypopigmentation, since such individuals possess, to a lesser or greater extent, physical characteristics that make them more visible.

The nocturnal behavior of bats may make them relatively less vulnerable to predation than most diurnal animals, although individuals affected by the mutation are more visible in their diurnal roosts than other bats (Rocha et al. 2013). Individuals affected by melanic mutations seek shelter in caves, mines, galleries and buildings in order to reduce predation pressure (Uieda 2000). Cave-dwelling behavior, as observed in the present study, may be essential for the survival of bats with depigmentation, since these environments provide protection against sunlight, water loss and visually oriented predators (Uieda 2000; Buys, Hejligers & Dorenbosch 2002).

Studies carried out with birds found that individuals with leucism and albinism have relatively shorter life spans in nature compared to normal individuals, since they are more frequently found by predators due to their attractive and distinct color (Santos 1981; Collins 2003). Corroborating these studies, Sazima & Di-Bernardo (1991) observed that cases of hypopigmentation are recorded more frequently in nocturnal species, cryptic species or species that are somehow protected from diurnal and visually oriented predators, which may explain the relatively high incidence of anomalous color patches in bats, as previously reported (Abreu et al. 2013).

Depigmentation in mammals represents a disadvantage in various ecological and biological contexts (Caro 2005). In addition to making mutated animals more susceptible to predation, depigmentation also hinders intraspecific communication and recognition and, in some cases, causes these individuals to be removed from social groups (Caro 2005). In the present study, we did not observe behaviors of exclusion of the leucistic individuals, and they were always captured amongst other bats that did not possess any such anomaly.

We observed that 1.1% of the population had some degree of depigmentation, which greatly exceeds the degree of rarity reported by Walter (1938) for albinism. According to this author, only one in 20,000 individuals may possess some form of albinism. Thus, we can assume that our results indicate a relatively high degree of anomalous coloration in the studied population, although no genetic study could be found that could give some kind of foundation. Considering that leucism is due to recessive gene expression (Møller & Moussaeu 2001), our results suggest that the studied population is isolated and that endogamy is occurring, as previously observed for birds by Bensch et al. (2000).

It is necessary to know the reasons that cause the appearance of these genetic anomalies of pelage coloration and their consequences for the affected individuals (Chacón et al. 2015). The need for genetic studies aimed to better understand these anomalies is in contrast to the low number of reports in Neotropical mammals in general (Abreu et al. 2013). Therefore, it is important that researchers report the occurrence of coloration anomalies in order to have a true dimension of the number of animals affected and thus facilitate the search for the causes and consequences of this phenomenon in bats and mammals in general (García-Morales et al. 2010).

Finally, it should be noted that the studied colony is located in an area of influence of mining activity. These areas suffer from severe impacts such as habitat suppression that may increase the isolation levels of bat populations occurring at these sites. In addition, these populations may be subject to more drastic impacts, such as the recent dam rupture at the Córrego do Feijão mine in the municipality of Brumadinho, located approximately 5 kilometers from the MJ-05 cave. Fortunately

Table 1. Date of collection, identification, forearm size (mm), body mass (g), sex and age of leucistic bats captured in a cave of the Quadrilátero Ferrífero (Iron Quadrangle), state of Minas Gerais, Brazil.

Capture date	Identification	Forearm length	Body mass	Sex	Age
Apr 28, 2017	AR076	41.2	13.4	Male	Subadult
Jun 27, 2017	AR121	42.4	16.5	Male	Adult
Jul 31, 2017	MZ694	42.0	16.0	Female	Adult
Sep 25, 2017	AR205	42.7	13.0	Female	Adult
Oct 31, 2017	AR323	41.7	12.0	Female	Adult
Oct 31, 2017	AR361	40.1	13.0	Male	Adult
Nov 29, 2017	AR300	42.1	13.0	Male	Adult
Mean		41.7	13.8		
Standard deviation		0.9	1.7		

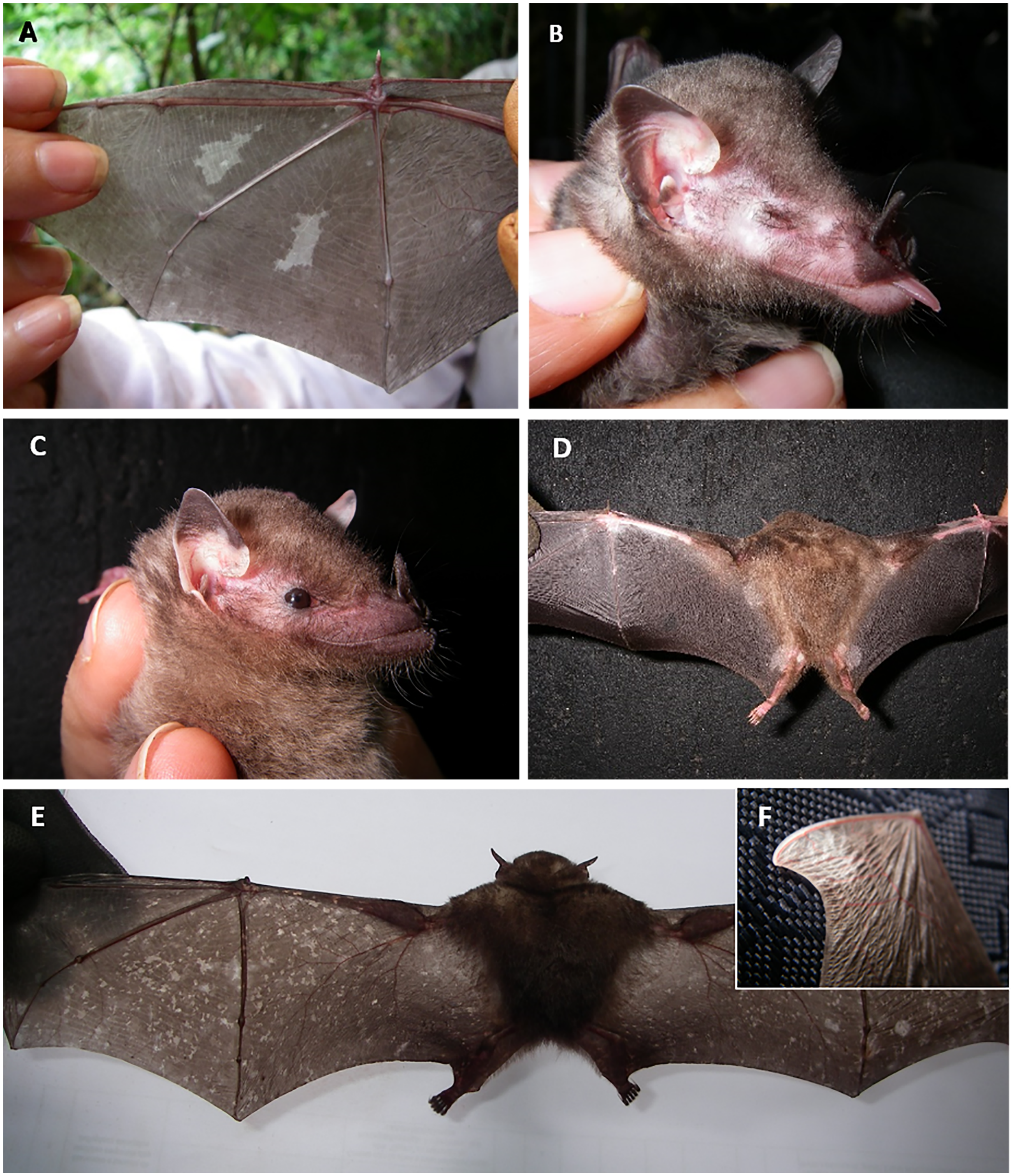

Figure 2. Specimens of *Anoura geoffroyi* with leucism captured in cave MJ-05 located in the municipality of Brumadinho, Minas Gerais, Brazil. A. Individual AR076 with detail of depigmentation of the wing between metacarpals III and V. B. Individual AR121 with depigmentation at the base of the ear, tragus and part of the rostrum. C and D. Specimen (voucher specimen MZ694) of *Anoura geoffroyi* with leucismo - Detail of depigmentation of the ears and plagiopatagium near the body. E. Individual AR300 with detail of depigmentation at several points on the wings. F. Individual AR323 with depigmentation at the extremity of the wing.

this rupture did not affect the shelter of the studied colony. However, for this population, the effects of the environmental destruction caused in the region can only be evaluated in future studies.

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Author Contributions

Aline da Silva Reis: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation.

Robson de Almeida Zampaulo: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation.

Sônia Aparecida Talamoni: Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Editorial

The 2nd Work Program of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services/IPBES*

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The 2nd Work Program of IPBES covers the period 2019 – 2030, and it is a rolling plan, i.e., it can be modified and adjusted to new requirements during its development. It aims to advance the achievement of the overall objective of IPBES, which is to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.

In line with the overall objective, the policy framework for the work program up to 2030 corresponds to the 2030 Agenda for Sustainable Development, including the Sustainable Development Goals, the biodiversity-related conventions and other biodiversity and ecosystem service processes (https://www.ipbes.net/development-next-work-programme-ipbes).

The rolling work program up to 2030 is entirely demand-driven, based on requests received from 5 multilateral environmental agreements, 4 United Nation bodies, 13 governments plus the European Union, and 10 NGOs (https://www.ipbes.net/requests-received-next-ipbes-work-programme). It is expected to inform all stakeholders in the implementation of their activities to support the achievement of the post-2020 global biodiversity framework and the 2050 vision for biodiversity, as well as other work under multilateral environmental agreements related to biodiversity. The work program may also inform the implementation of the Paris Agreement with respect to matters related to the links between biodiversity and climate change. It also places strong emphasis on promoting collaboration among science, policy and practice; scientific disciplines; different types of knowledge; and the four functions of IPBES, up to 2030.

The new work program is guided by the operating principles of IPBES, which are to collaborate with existing initiatives on biodiversity and ecosystem services; to be scientifically independent and ensure credibility, relevance and legitimacy through peer review of its work and transparency in its decision-making process; to use clear, transparent and scientifically credible processes for the exchange, sharing and using of data, information and technologies; to recognize and respect the contribution of indigenous and local knowledge to the conservation and sustainable use of biodiversity and ecosystems; to provide policy-relevant information, but not policy-prescriptive advice; to integrate capacity-building into all relevant aspects of its work; to recognize the unique biodiversity and scientific knowledge thereof within and among regions and the need for the full and effective participation of developing countries and balanced regional representation and participation in its structure and work; to take an interdisciplinary and multidisciplinary approach; to recognize the need for gender equity in all relevant aspects of its work; to address terrestrial, marine and inland water biodiversity and ecosystem services and their interactions; and to ensure the full use of national, subregional and regional knowledge, as appropriate, including by ensuring a bottom-up approach.

The rolling work program up to 2030 initially focuses on three topics arising from the prioritization of the responses to the first call for requests, inputs and suggestions (see a draft version at https://www.ipbes.net/system/tdf/ipbes-7-6_en_next_wp.pdf?file=1&type=node&id=29738). The three topics, which are all aligned with the overall objective of IPBES and its policy framework, are:

(a) Promoting biodiversity to achieve the 2030 Agenda for Sustainable Development: the Sustainable Development Goals related to biodiversity need to be achieved simultaneously with the other goals, especially those that are strongly linked to biodiversity through impact and/or dependence. The challenge is to achieve health for all, with food, water and energy security, including through the enhanced use of biodiversity, without adversely impacting biodiversity, water quality or climate and in the context of global change, including climate change. To address this challenge, the deliverables under this topic will look at the interlinkages among biodiversity, water, food and health and between biodiversity and climate change, with a view to informing the development of policies and actions;

(b) Understanding the underlying causes of biodiversity loss and determinants of transformative change to achieve the 2050 vision for biodiversity: Achieving the 2050 vision in conjunction with key human development goals requires fundamental changes at many levels, from individuals through communities and businesses to society at large. The deliverables related to this topic are aimed at understanding and identifying factors in human society at both the individual and collective levels, including behavioral, social, cultural, economic, institutional, technical and technological dimensions, that can be leveraged to bring about transformative change in favor of biodiversity while taking into account broader social and economic imperatives in the context of sustainable development;

(c) Measuring business impact and dependence on biodiversity and nature's contributions to people: Appropriate tools for measuring dependence and impact are crucial to enabling businesses to assess and monitor their dependence and impact with a view to reducing adverse effects and related material and reputational risks, and to developing the business case for long-term sustainability. They are also important for promoting public accountability, informing regulatory agencies and guiding financial investments. Deliverables under this topic include categorization of the ways in which businesses depend on, and impact, biodiversity and nature's contributions to people, and work related to criteria and indicators for measuring this dependence and impact, taking into consideration how such metrics can be integrated into other aspects of sustainability.

The planned assessments included in this new work program are:

(a) A thematic assessment of the interlinkages among biodiversity, water, food and health.
(b) A technical paper on the interlinkage between biodiversity and climate change.
(c) A thematic assessment of the underlying causes of biodiversity loss and the determinants of transformative change.
(d) A methodological assessment of the impact and dependence of business on biodiversity and nature's contributions to people.

*This text has been adapted from document IPBES 7/6

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Inventory

Medium and large mammals in a *Cerrado* fragment in Southeast Goiás, Brazil: inventory and immediate effects of habitat reduction on species richness and composition

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Abstract: The reduction and fragmentation of remnant vegetation habitats has been one of the main threats to Cerrado biodiversity. The aim of the present study is to make an inventory of medium and large mammal species in a Cerrado remnant and to assess deforestation influence on part of this fragment on the richness and composition of mammal species. The study was conducted in a Cerrado fragment in southeast Goias State, Ipameri County. Data were collected during three different periods (P1, January-June, 2014; P2, December, 2016 – June, 2017; P3, July-December, 2017) through direct (visual, vocal and camera-trap records) and indirect methods (foot prints, animal burrows and other traces) in order to register the mammal species. Jackknife 1 estimator was used to estimate species richness during each of the three sampled periods and for the complete collection period; species similarity between periods was assessed through the Jaccard's Index of Similarity (Cj). Species richness between periods was performed through inference by overlapping confidence intervals (CI). Twenty-nine species were recorded during the assessed period, five of them were listed as endangered in Brazil. There was no significant change in species richness between the assessed periods: species richness of 25 species was observed in Period 1 (P1), the richness of 32 species was estimated (CI = 4.58); 23 species were recorded in Period 2 (P2), and the richness of 30 species was estimated (CI = 4.39), the richness of 23 species was observed in Period 3 (P3) and the richness of 28 species was estimated (CI = 4.70). Similarity in species composition between the assessed periods recorded Cj = 0.71 (71%) between P1 and P2, Cj = 0.66 (66%) between P1 and P3, and Cj = 0.77 between P2 and P3. Fragment deforestation did not influence the richness and composition of medium and large mammal species (within a period of 2~3 years) when the three periods were compared; however, the absence of changes in the community can be the result of time-lag, therefore, we cannot put aside the likelihood of mid and long-term effects.

Keywords: *mammal fauna; wildlife survey; species composition; fragmentation.*

Mamíferos de médio e grande porte em um fragmento de Cerrado, no sudeste de Goiás, Brasil: inventário e efeitos imediatos da redução de habitat na riqueza e composição de espécies

Resumo: A fragmentação e a redução de hábitat de vegetação remanescente tem sido as principais ameaças à biodiversidade do Cerrado. Este trabalho teve como objetivo inventariar as espécies de mamíferos de médio e grande porte em um fragmento de Cerrado e avaliar a influência do desmatamento de parte desse fragmento na riqueza e composição de espécies de mamíferos. O estudo foi conduzido em um fragmento de Cerrado, no sudeste do Estado de Goiás, município de Ipameri. Os dados foram coletados em três períodos (P1 - janeiro-junho/2014, P2 - dezembro/2016-junho/2017 e P3 - julho-dezembro/2017) utilizando métodos diretos (visual, vocal e registros fotográficos) e indiretos (pegadas, tocas e outros sinais) para o registro das espécies de mamíferos. Foi estimada a riqueza de espécies para os três períodos amostrados e para todo período utilizando o estimador Jackknife 1 e a semelhança de espécies entre os períodos, pelo Índice de Similaridade de Jaccard (Cj). A comparação da riqueza de espécies estimada entre os períodos foi realizada pela inferência por sobreposição dos intervalos de confiança (IC). Em todo o período estudado foram registradas 29 espécies, sendo 5 destas listadas como ameaçadas de extinção no Brasil. Entre os períodos amostrados não foi observada mudança significativa na riqueza de espécies, sendo que no período 1 (P1) foi observada a riqueza de 25 espécies e estimada de 32 (IC = 4,58), no período 2 (P2) registrou-se 23 espécies e estimou-se 30 (IC = 4,39) e no período 3 (P3) a riqueza observada foi de 23 espécies e estimada 28 (IC = 4,70). A similaridade na composição de espécies entre os períodos foi de Cj = 0,71 (71%) entre P1 e P2, Cj = 0,66 (66%) entre P1 e P3 e Cj = 0,77 entre P2 e P3. Não foi observada influência do desmatamento do fragmento (no período de 2 a 3 anos) na riqueza e composição de espécies de mamíferos de médio e grande porte, comparando os três períodos amostrados. Contudo, a ausência de alterações na comunidade pode ser decorrente de um time-lag, não podendo descartar possíveis efeitos a médio e longo prazo.

Palavras-chave: *mastofauna, levantamento de fauna, fragmentação, perda de habitat.*

Introduction

Habitat fragmentation and loss processes have been seen as the main threats to biodiversity (Ahumada et al. 2011, Gibson et al. 2011). These processes change the disposition and habitat connectivity, but they are different. The fragmentation turns areas into smaller remnants at different isolation levels, whereas the habitat loss does not necessarily cause any disruption in fragment continuity (Fahrig 2003).

It is possible to observe changes in the landscape and in connectivity, as well as increase in the matrix area and in the border effect, after fragmentation (Uezu et al. 2005, Michalski & Peres 2007, Norris et al. 2008). These changes can lead to alterations in local biodiversity, either at population level – such as changes in abundance, reproduction; in the distribution, recruiting and survival rates of individuals (Wolff et al. 1997, Fahrig 2003) – or at community level, as well as changes in species richness and composition (Chiarello 1999, Santos-Filho et al. 2012).

Habitat reduction and fragmentation can cause many losses to the fauna, such as reduction in shelter, food availability and in the availability of reproduction locations. Moreover, this reduction can increase or reduce fauna flow depending on the affected species, fact that exposes these species to predators and hunters (Cullen Jr. et al. 2000, Peres 2000). One additional effect of habitat reduction or fragmentation is population isolation, that is responsible for gene flow reduction, which, consequently, leads to reduction in local fauna population and even to the extinction of some species in the region (Fahrig 2003). The ability of some species to remain in fragmented sites is related to their biological characteristics, such as body size (Rocha et al. 2018), area for use, population density, specificity of habitat use, reproduction rate (Arita et al. 1990, Cardillo & Bromham 2001, O'Grady et al. 2004) and their ability to cross large unfavorable areas (Dale et al. 1994).

The Cerrado biome covers approximately 23% of the national territory and it was included among the 34 hotspots in the planet due its high biodiversity, degree of endemism and endangerment (Mittermeier et al. 2005). Cerrado has been facing the fast reduction of its original vegetal cover in the last five decades given the expansion of agricultural frontiers in Central Brazil. Therefore, this biome is currently highly fragmented in many regions (Sano et al. 2007, Carvalho et al. 2009, Strassburg et al. 2017).

Cerrado houses at least 251 mammal species; 32 of them are endemic and 16 are listed as endangered in Brazil (Paglia et al. 2012, MMA 2014). The mammals has been considered as one of the biologic groups mostly influenced by habitat fragmentation, due to the characteristics of their species, since most of them need large areas to live (at certain preservation degree), have higher demands for resources in order to survive and present low reproduction rates (Cardillo et al. 2005).

Studies about Cerrado assessing the effects of fragmentation on wild mammals remain scarce; thus, the aim of this study was to survey medium and large mammal species in a Cerrado fragment in Southeast Goias State and to assess deforestation influence on the richness and composition of mammal species.

Material and Methods

1. *Study site*

The study was conducted in a Cerrado fragment (coordinates: 17°40'31" S; 48°05'09" W) in southeast Goias State, Ipameri County (Figure 1). The private property where the research was conducted holds Cerrado remnants that exceed the minimal requirements for rural real estate (Brasil, 2012). However, part of this native vegetation was legally removed between 2014 and 2017, with emphasis to soil use for agricultural purposes.

Part of the natural vegetation in the fragment where the study was conducted was suppressed. Before the beginning of vegetation suppression, in 2014, the fragment has an area of 284 ha; between December 2016 and July 2017, the area was reduced to 204 ha, thus it lost 28% of its native vegetation cover; and from July to December 2017 the area was reduced to 196 ha, 30.9% loss in relation to 2014 (Figure 1).

2. *Sampling*

Data were collected between 2014 and 2017 during three different periods: January-July, 2014 (P1) [sample effort (n)=4 days], December, 2016 – June, 2017 (P2) [n=6 days] and July-December, 2017 (P3) [n=6 days].

Active searches were performed, totaling 64 hours, and the species were recorded through direct (visual and vocal) and indirect methods (foot prints, animal burrows and other traces) (Rocha et al. 2015). In addition, two camera traps (Bushnell, digital - 8 mega pixel resolution) were used between December 17, 2016 and December 28, 2017, when

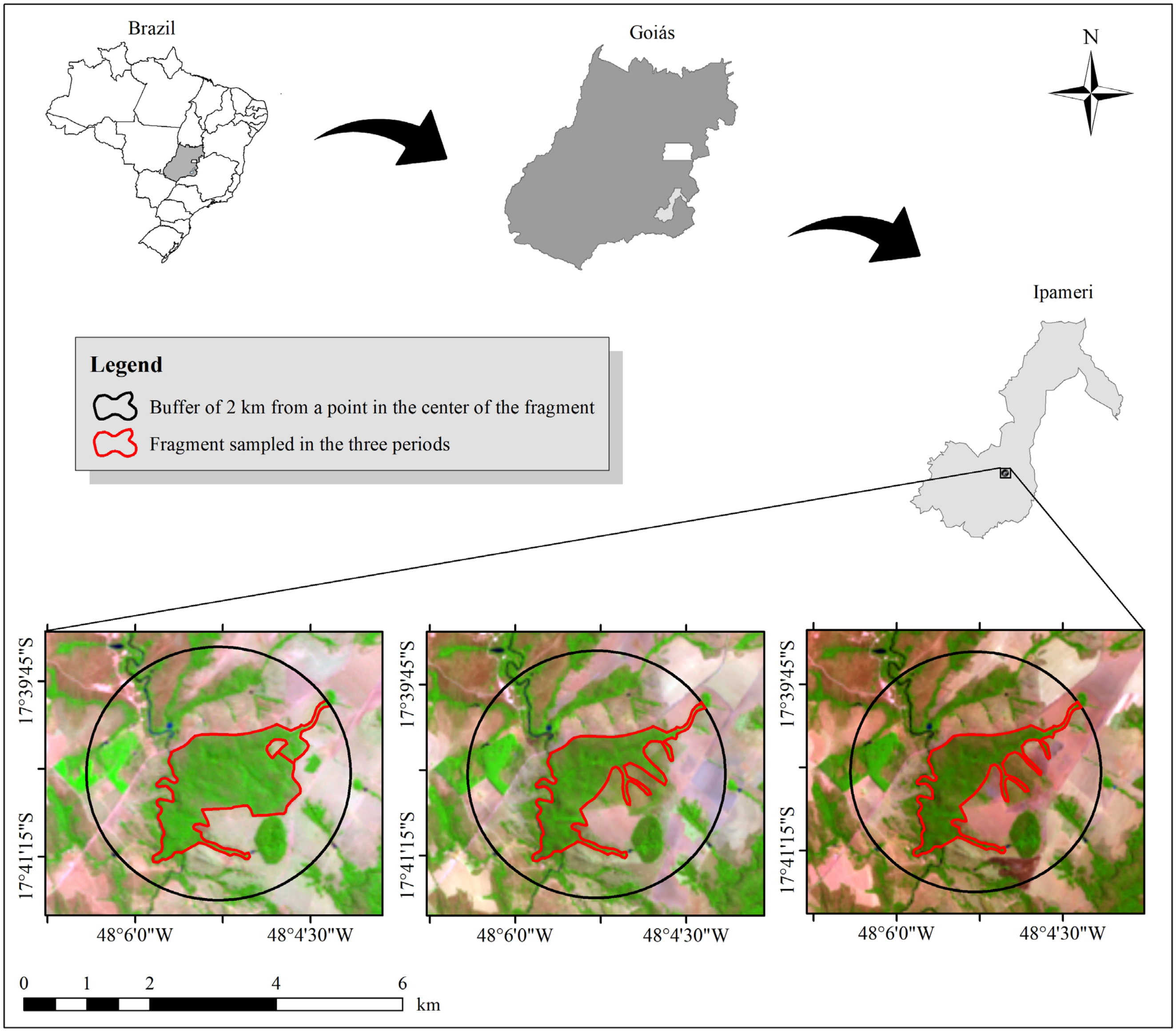

Figure 1. Location of the sampled fragment and fragment situation in each period [Period 1 (P1): January, 2014 – 284ha; Period 2 (P2): December, 2016 – June, 2017 – 204ha; and Period 3: July-December, 2017 – 196ha], Ipameri County, southeast Goias state.

these traps were removed from, or reinstalled in, different spots, without baits, in locations likely crossed by the local fauna. This method totaled 376 traps-night sampling effort.

The active searches were performed in roads, tracks, banks of water courses and in their surroundings. The study site was randomly crossed in search for evidences of medium and large mammals. When any animal was visualized or when any evidence of mammals was found, they were identified (Becker & Dalponte 2013) and recorded in a field book along with information about the location and type of sampled environment. In this study, the taxonomic arrangement followed Paglia et al. (2012).

3. *Data analysis*

The landscape in a 2km radius was measured from a spot in the center of the assessed fragment to quantify the habitat extension within the fragment. Two classes of landscape classification were adopted: 1) Habitat – Forest and/or denser Cerrado areas; 2) non-habitat – areas with altered original vegetation, fields, lakes and rivers (Rocha et al. 2018).

Species accumulation curves were generated from records of each mammal species collected in the study site through each of the used sampling methods (active search and camera trap), based on the rarefaction method (Gotelli & Colwell 2011). Moreover, species richness in each sampled period was estimated in the Jackknife 1 estimator. The comparison of estimated species richness between periods was performed through inferences by confidence intervals. Thus, confidence interval overlap between a period and the mean richness of other period indicated similar species richness (Coelho et al. 2014). Species similarity among the three periods was measured through the Jaccard's Index of Similarity (Cj), which was adopted to generate a dendrogram through the unweighted pair group method with arithmetic averages (UPGMA).

The statistical analyses were conducted in the R *Software* (R Core Team 2018) – vegan package (Oksanen et al. 2018). Only data collected through active search were used to compare the assessed periods in order to standardize the methods used between periods, since Period 1did not use camera traps.

Results

1. *Species inventory*

Twenty-nine medium and large mammal species were recorded (table 1 and Figure 2) during the research. These species were divided in 8 orders: Carnivora (11 species), Cingulata (5 species), Primates (3 species), Cetartiodactyla (3 species), Didelphimorphia (2 species), Pilosa (2 species), Rodentia (2 species) and Lagomorpha (1 species). Five of the recorded species were classified as endangered in Brazil (MMA, 2014): Giant anteater (*Myrmecophaga tridactyla*), Giant armadillo (*Priodontes maximus*), Cougar (*Puma concolor*), Maned wolf (*Chrysocyon brachyurus*) and Hoary fox (*Lycalopex vetulus*).

Species accumulation curves for this study not showed stabilization complete trend either in the active search or in the camera traps. This outcome indicates that the sampling effort, although good for small areas, not was enough to represent all species of the mammal fauna in the study site (Figure 3). Therefore, an increase in the sampling effort is expected to reveal some species not recorded in this study.

2. *Effects of habit loss on species richness and composition*

The assessed fragment covered 284ha before de deforestation period, which corresponds to Period 1 (P1); the landscape it was inserted in had 486ha. It presented the observed richness of 25 species and the estimated richness of 32 ones (confidence interval – CI=4.58). Period 2 (P2) showed that the fragment had its territory reduced to 204 ha, 28% loss of its size and the habitat in the landscape recorded 16.5% reduction, it dropped to 406ha – 23 species and 30 estimates (CI=4.39). Period 3 (P3) recorded fragment area 196ha and the habitat in the landscape dropped down to 398ha, 23 species and 28 estimates (CI-4.70) (Table 2). The loss in fragment area reached 30.9%, whereas the habitat loss in the landscape within a 2km radius recorded 18.1%.

Table 1. Medium and large mammal species recorded in a Cerrado fragment, Ipameri County – GO, during three periods: P1 = Jan-Jul/2014, P2 = Dec/2016-Jun/2017 and P3 = Jul-Dec/2017. Type of record: F = foot print, Vi = visual, Vo = vocal, B = burrow, Ca = carcass and Ct = camera trap. * endangered species (MMA, 2014).

Taxon	Common name	P1	P2	P3
Didelphimorphia				
Didelphidae				
Didelphis albiventris Lund 1840	Brazilian White-eared Opossum		F, Ct	F, Ct
Chironectes minimus (Zimmermann, 1780)	Water Opossum	F		
Pilosa				
Myrmecophagidae				
Tamandua tetradactyla (Linnaeus, 1758)	Southern Tamandua	F	F	F, Ct
Myrmecophaga tridactyla Linnaeus, 1758*	Giant anteater	F	F, Ct	F, Ct
Cingulata				
Dasypodidae				
Cabassous unicinctus (Linnaeus, 1758)	Southern Naked-tailed Armadillo	B		
Cabassous tatouay (Desmarest, 1804)	Greater Naked-tailed Armadillo		Ct	B
Euphractus sexcinctus (Linnaeus, 1758)	Six-banded Armadillo	F, B	F, B	F
Dasypus novemcinctus Linnaeus, 1758	Nine-banded Armadillo	F, B	P, Ct	F, B
Priodontes maximus (Kerr, 1792)*	Giant Armadillo	F, B	F, B, Ct	F, B
Cetartiodactyla				
Cervidae				
Mazama gouazoubira (G. Fischer, 1814)	South American Brow Brocket	F, Vi	F, Ct	F, Vi, Ct
Mazama americana (Erxleben, 1777)	South American Red Brocket	F	F	F
Tayassuidae				
Pecari tajacu (Linnaeus, 1758)	Collared Peccary	F	F, Vo, Ct	F, Ct
Primates				
Atelidae				
Alouatta caraya (Humboldt, 1812)	Black-and-Gold Howler Monkey		Vo	F, Vi, Vo, Ca
Cebidae				
Sapajus libidinosus (Spix, 1823)	Bearded Capuchin		Vi	Vi

Continuation Table 1.

Taxon	**Common name**	**P1**	**P2**	**P3**
Callitrichidae				
Callithrix penicillata (É. Geoffroy, 1812)	Black-tufted-ear Marmoset	Vi		
Carnivora				
Canidae				
Lycalopex vetulus (Lund, 1842)*	Hoary Fox	F	F	F
Cerdocyon thous (Linnaeus, 1766)	Crab-eating Fox	F	F	F
Chrysocyon brachyurus (Illiger, 1815)*	Maned Wolf	F	F	
Felidae				
Puma concolor (Linnaeus, 1771)*	Cougar	F	F	F
Leopardus pardalis (Linnaeus, 1758)	Ocelot	F	F	F, Ct
Small Felidae not identified		F	F	
Mustelidae				
Eira barbara (Linnaeus, 1758)	Tayra	F	Ct	F, Ct
Lontra longicaudis (Olfers, 1818)	Neotropical Otter	F	F	F
Procyonidae				
Nasua nasua (Linnaeus, 1766)	South American Coati	F	F, Ct	F, Vi, Ca, Ct
Procyon cancrivorus (G. Cuvier, 1798)	Crab-eating Raccoon	F	F	
Mephitidae				
Conepatus semistriatus (Boddaert, 1785)	Striped Hog-nosed Skunk	F	F	F
Lagomorpha				
Leporidae				
Sylvilagus brasiliensis (Linnaeus, 1758)	Tapeti	F	F, Ct	F, Ct
Rodentia				
Caviidae				
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Capybara	F		F
Cuniculidae				
Cuniculus paca (Linnaeus, 1766)	Spotted Paca	F	F	F, Ct
Registers in active search (p, Vi, Vo, F, B, Ca)		**25**	**23**	**23**
Registers in camera trap (Ct)		**-**	**10**	**10**
Total of species		**25**	**25**	**23**

There was no statistically significant differences of mammal species richness between the sampled periods. Values resulting from the observed richness in the three periods were very close, besides the considerable overlap between confidence intervals and estimated richness (Table 2).

Species similarity between periods 1 and 2 was Cj = 0.71 - these periods shared 20 species. Periods 1 and 3 were similar, Cj = 0.66 – they shared 19 species; periods 2 and 3 were similar, Cj = 0.77 – they shared 20 species (Figure 4).

Discussion

The richness of mammal species observed during the entire study (29 species) can be classified as high, given the fact that the sampled fragment was relatively small. This outcome evidences the importance of Legal Reservation and Permanent Preservation areas, as the fragment sampled in the present study, for the conservation *in situ* of Cerrado mammal fauna, especially for endangered species. Estrela et al. (2015) conducted a comparative study in a mosaic composed of Cerrado fragments (512 ha) located approximately 25km from the herein sampled fragment and recorded 25 mammal species. Rocha et al. (2015) studied a 618ha fragment located approximately 95km from our study site and recorded 23 medium and large mammal species. Their outcomes confirm the high richness of mammal fauna in the Cerrado biome in southeast Goias state.

The order Carnivora recorded the highest observed richness, 11 species, which corresponds to 37.9% of the species recorded in the site. This result is close to that recorded by other authors Bocchiglieri et al. (2010) in the Cerrado biome and by Hannibal (2014), in the Atlant forest biome. This order was followed by Cingulate, which presented 5 species – 17.2% of the species found. Individuals belonging to order Carnivora are often distributed in fragmented landscapes and most

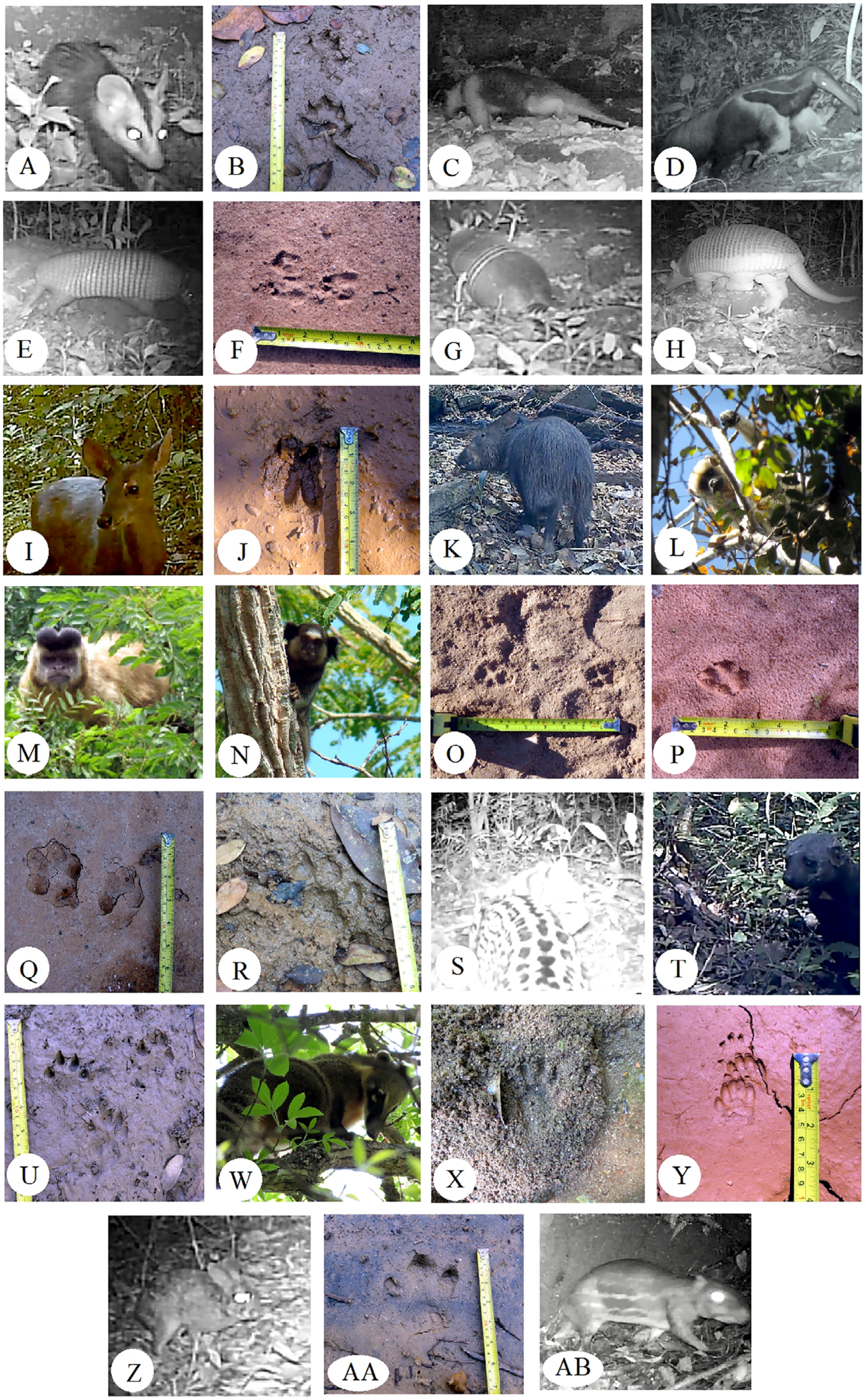

Figure 2. Recorders of medium and large mammal species in a Cerrado fragment in Southeast Goias State between 2014 and 2017: **A** = *Didelphis albiventris*, **B** = *Chironectes minimus*, **C** = *Tamandua tetradactyla*, **D** = *Myrmecophaga tridactyla*, **E** = *Cabassous tatouay*, **F** = *Euphractus sexcinctus*, **G** = *Dasypus novemcinctus*, **H** = *Priodontes maximus*, **I** = *Mazama gouazoubira*, **J** = *Mazama americana*, **K** = *Pecari tajacu*, **L** = *Alouatta caraya*, **M** = *Sapajus libidinosus*, **N** = *Callithrix penicillata*, **O** = *Lycalopex vetulus*, **P** = *Cerdocyon thous*, **Q** = *Chrysocyon brachyurus*, **R** = *Puma concolor*, **S** = *Leopardus pardalis*, **T** = *Eira barbara*, **U** = *Lontra longicaudis*, **W** = *Nasua nasua*, **X** = *Procyon cancrivorus*, **Y** = *Conepatus semistriatus*, **Z** = *Sylvilagus brasiliensis*, **AA** = *Hydrochoerus hydrochaeris*, **AB** = *Cuniculus paca*.

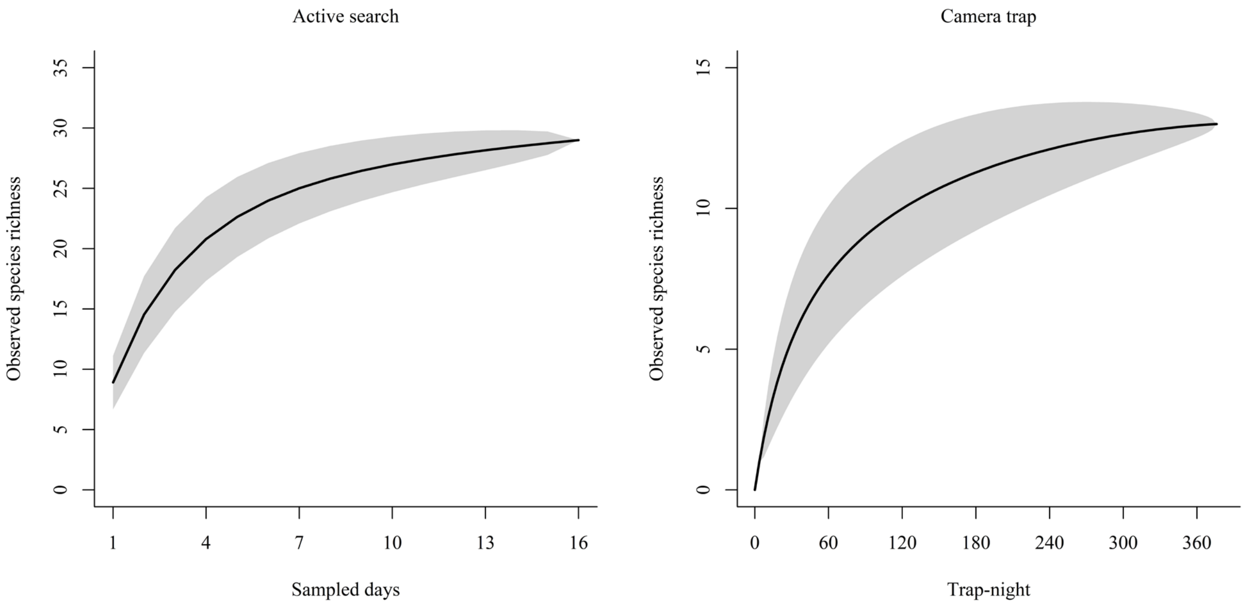

Figure 3. Rarefaction curves of the richness of medium and large mammal species recorded through active search and camera traps in a Cerrado fragment, southeast Goias, Ipameri County – GP, between 2014 and 2017.

Table 2. Fragment size (FS), fragment reduction (FR%), amount of habitat in the landscape within a 2km radius from the center of the fragment (AH), habitat reduction in the landscape (HRL%), observed species richness (OR), estimated species richness (ER) and confidence interval (CI).

Periods	FS (ha)	FR%	AH (ha)	HRL%	OR	ER (CI)
P1 (Jan-Jun/2014)	284	-	486	-	25	32 (4.58)
P2 (Dec/2016-Jun/2017)	204	28.16	406	16.5	25	30 (4.39)
P3 (Jul-Dec/2017)	196	30.9	398	18.1	23	28 (4.70)

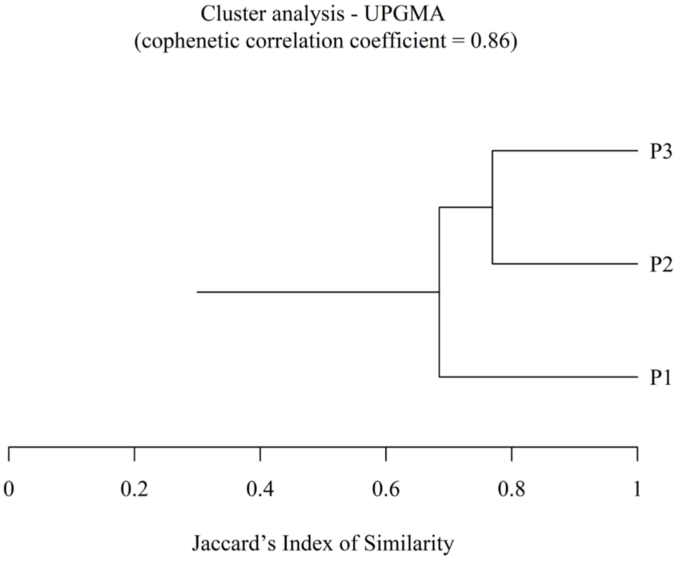

Figure 4. Dendrogram of the UPGMA based on the species similarity index among the three sampled periods (P1 = Jan-Jul/2014, P2 = Dec/2016-Jun/2017 and P3 = Jul-Dec/2017) in a Cerrado fragment in Ipameri County, southeast Goias state.

species have great mobility and the ability to explore anthropized areas (Lyra-Jorge et al. 2008), a fact that might explain the high richness of these orders in the assessed fragment.

The present results do not evidence significant differences in species observed richness before and after vegetation suppression, since the time interval after habitat change was short (2-3 years) for the occurrence of radical changes in species richness. Zimbres et al. (2013) analyzed five species of Xenarthra in Cerrado and they did not find any differences of activity pattern between more or less fragmented areas. However, there was positive relation between mammal species richness and the size of forest fragments; such outcomes have already been shown in studies conducted with big-sized mammals in Atlantic Forest areas in Espirito Santo State (Chiarello 1999) and in the Brazilian southern Amazon (Michalski & Peres 2007, Santos-Filho et al. 2012).

Some short-term changes in biodiversity can be observed after alterations in landscape, but some species have their population reduced, or even vanished, after a long period of time (Kuussaari et al. 2009). Species in a community need time (relaxation time) to adapt to new conditions after structural changes in the landscape and to regain balance (Kuussaari et al. 2009). This process can lead to two scenarios: first, the extinction debit, which happens when the limit condition for species survival after habitat loss is not reached. However, these species did not disappear yet due to their delayed response to environmental changes, but they will disappear with time (Tilman 1994, Jackson & Sax 2009). Second, immigration credit, which increases the number of local species because the environment becomes appropriate for the occupation of new species. As long as the extinction debit and the immigration credit are over, the community returns to balance and biodiversity is finally restored (Jackson & Sax 2009). According to Kuussaari et al. (2009), studies assessing the time interval between habitat changes and species responses open room for three hypothesis concerning factors that determine the likelihood and intensity of an extinction debit: (1) extinction debits must change depending on the biological characteristics of the affected species; (2) the intensity of an extinction debit must present non-linear relation to the intensity of habitat changes; e (3) extinction debits should decrease over time after habitat modification.

The number of species found in a fragment is linked either to habitat size or to the amount of habitat in the landscape; the richness of a fragment must increase according to the total amount of habitat in the local landscape (Fahrig 2013). On the other hand, as the habitat loss progresses, species richness in a certain type of habitat in the total landscape will diminish along with the total remnant area of the type of landscape, regardless of the individual size of the remaining fragments (Fahrig 2013).

Although there were no significant changes in species richness in the sampled periods, it is likely that such changes will happen in the long-term, since the extinction debits are much more likely to happen in landscapes that face intermediate habitat loss (~20-30%) than in landscapes that lose little or many habitats (Lira et al. 2012). Our results showed 30.9% fragment area loss and 18.1% landscape loss – extinction debit was expected. According to Hanski & Ovaskainen (2002), yet, many species can persist for a long time close to the minimum habitat quality conditions necessary for population maintenance and to the extinction limits in landscapes where the habitat loss was intermediate. On the other hand, many species can persist for a long period in little habitat loss landscapes without facing strong adverse impact. Extinctions are expected to happen fast in landscapes facing very intense habitat loss (Lira et al. 2012).

Hunting is another important factor to be taken into account as it can influence the extinction of local mammal species, mainly of big-sized ones. This same pattern was detected and highlighted as relevant in other studies (Cullen Jr. et al. 2000, Peres 2000), because populations living in smaller fragments tend to be more vulnerable to predation and to be hunted by humans. Although hunting by humans was not observed in the assessed fragment, there were domestic dogs often hunting in the area, which can promote attacks on wild animals (Mendes et al. 2005, Silva & Henrique, 2009).

Species compositions was similar between the sampled periods (Figure 4), but it did not show evidence drastic changes due to habitat reduction. The small difference in similarity mainly happened due to the occasional record of some species that were observed only in one field survey, such Water Opossum (*Chironectes minimus*), Southern Naked-tailed Armadillo (*Cabassous unicinctus*), Greater Naked-tailed Armadillo (*Cabassous tatouay*), Black-tufted-ear Marmoset (*Callithrix penicillata*) and other species that were recorded in some periods and not recorded in others – even if the environment in the non- recorded periods favored the presence of such species.

Great changes in the richness and composition of medium and large mammal species were not observed in the assessed fragment during the sampled periods. According to Metzger et al. (2009), some species can be sensitive to changes in part of the landscape rather than to changes in the internal conditions or in areas of the fragment they occupy. Moreover, species presenting more ability to use habitats inserted in a matrix and to displace between fragments, such as medium and large mammals, can move and occupy different environments in a matrix. Consequently, they can be less affected by habitat fragmentation processes (Umetsu et al. 2008).

Semper-Pascual et al. (2018) observed that relaxation time (the time needed for a certain community to reach balance after landscape change) for birds and mammals in the *Chaco Seco Argentino* was 10 to 25 years. We cannot highlight the possible mid and long-term effects on mammal species, since we did not find deforestation effects on the richness and composition of these species in the short-term (2~3 years). Therefore, the absence of changes in the community can derive from time-lag. These changes in composition of mammals species should occur in a time greater than the duration of this study.

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Author Contributions

Ednaldo Cândido Rocha and Jhefferson Silva: concept and design of the study, performed collection of field data, and carried out the data analysis and wrote the paper.

Pablo Timóteo da Silva: contribution in the collection of field data.

Márcio da Silva Araújo and André Luis da Silva Castro: contribution in the data analysis, critical revision, and adding intellectual content.

Conflicts of interest

The authors declare no conflict of interest related to the publication of this manuscript.

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Article

Vanilla bahiana Hoehne (Orchidaceae): studies on fruit development and new perspectives into crop improvement for the *Vanilla planifolia* group

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Abstract: *Vanilla* is the most well-known and economically important genus of Orchidaceae in the world. *Vanilla bahiana* is restricted to Brazil and its conservation status was recently assessed as 'Endangered'. The species is phylogenetically closely related to *V. planifolia*, whose pods are the main natural source of vanillin. The primary desirable traits for vanilla production are high fruit set and great resistance to abiotic stress. High temperatures (> 32ºC) and heavy rain favor fungal infection, and thus are indirectly responsible for fruit drop by *V. planifolia* in cultivation. The aim of the present study was to follow the process of pod ripening of *V. bahiana* in a restinga fragment in an Environmental Protection Area of Bahia State, and to highlight implications for vanilla crop improvement. Fieldwork was carried out from April 2016 to January 2017. A total of nine manual self-pollinations and nine manual cross-pollinations were successfully carried out. Fruit length, diameter and girth were recorded every two weeks. Fruit permanence in the infrutescence was measured as consecutive days from pollination. Descriptive statistics were calculated and Pearson correlation analysis performed among all attributes per pollination method. The influence of temperature and rainfall was also analyzed. Pod measurements and fruit permanence in the infrutescence were higher for cross-pollination than self-pollination. Higher rainfall results in fruit drop. The use of *V. bahiana* in breeding efforts for the genus is here strongly suggested and supported by previously published studies that allowed us to highlight several desirable traits: vanillin production, its wide geographical distribution and occurrence in a variety of habitats; substantial populations; resistance to conditions of drought and high luminosity and temperature; extensive blooming period; high number of flowers per raceme; possible synchronised flowering with *V. planifolia*, and fruiting throughout the year. These prospects are promising and should be further evaluated, not only for *V. bahiana* but for other vanilla crop wild relatives. Studies of pollination ecology can be used to set guidelines for the conservation of the *V. planifolia* group and to encourage the development of strategies to increase the production of fruit and, consequently, vanillin for its culinary uses and medical applications.

Keywords: *Bahia State, Brazil, conservation, crop wild relative, vanilla production.*

Vanilla bahiana Hoehne (Orchidaceae): estudos sobre o desenvolvimento dos frutos e novas perspectivas para o melhoramento de culturas do grupo *Vanilla planifolia*

Resumo: *Vanilla* é o gênero mais bem conhecido e economicamente importante de Orchidaceae no mundo. A espécie *Vanilla bahiana* é restrita ao Brasil e seu estado de conservação foi recentemente avaliado como "Em Perigo". A espécie é filogeneticamente próxima de *V. planifolia*, cujos frutos são a principal fonte natural de vanilina. As principais características desejáveis para a produção de baunilha são o elevado número de frutos e grande resistência ao estresse abiótico. Altas temperaturas (> 32 º C) e fortes chuvas favorecem a infecção fúngica, sendo, portanto, indiretamente responsáveis pela queda de frutos de *V. planifolia* em cultivo. O objetivo do presente estudo foi acompanhar o processo de maturação do fruto de *V. bahiana* em um fragmento de restinga em uma Área de Proteção Ambiental do estado da Bahia e destacar as implicações para o melhoramento da cultura da baunilha. O trabalho de campo foi realizado de abril de 2016 a janeiro de 2017. Um total de nove autopolinizações manuais e nove polinizações cruzadas manuais foram realizadas com sucesso. O comprimento, o diâmetro e a circunferência dos frutos foram registrados a cada duas semanas. A permanência do fruto na infrutescência foi medida através de dias consecutivos a partir da polinização. Medidas estatísticas descritivas dos atributos morfométricos foram calculadas e a análise de correlação de Pearson foi realizada para verificar a associação entre os pares dos atributos por método de polinização. Também foi analisada a influência da temperatura e da precipitação pluviométrica. As medidas do fruto e a permanência do fruto na infrutescência foram maiores na polinização cruzada do que na autopolinização. O aumento dos índices pluviométricos resulta em queda de frutos. O uso de *V. bahiana* em esforços de melhoramento para o gênero é fortemente sugerido aqui e suportado por estudos publicados anteriormente, que nos permitiram destacar várias características desejáveis: a produção de vanilina; ampla distribuição geográfica e ocorrência em diversos domínios fitogeográficos; formação de populações substanciais; resistência às condições de seca, alta luminosidade e temperatura elevada; extenso período de floração; elevado número de flores por racemo; possível florescimento sincronizado com *V. planifolia*; e frutificação ao longo do ano. Essas perspectivas são promissoras e devem ser avaliadas não apenas para *V. bahiana*, mas também para outras espécies de *Vanilla* restritas ao Brasil. Estudos de ecologia de polinização podem ser usados para estabelecer diretrizes para a conservação do grupo *V. planifolia* e encorajar o desenvolvimento de estratégias para aumentar a produção de frutos e, consequentemente, de vanilina para usos culinários e aplicações médicas.

Palavras-chave: *Bahia, Brasil, conservação, parente silvestre de cultivar, produção de baunilha.*

Introduction

Vanilla Mill. is the most well-known and economically important genus of Orchidaceae in the world (e.g. Correll 1953, Ramachandra & Ravishankar 2000, Lubinsky et al. 2008a). Beans of *Vanilla* spp., mainly *Vanilla planifolia* Jacks. ex Andrew, are natural sources of vanillin and vanilla extracts, which are widely used in different cuisines and perfumes (Childers & Cibes 1948, Bythrow 2005, Havkin-Frenkel & Belanger 2011). Furthermore, vanillin has been found to be anticarcinogenic, anticlastogenic, antimicrobial and antimutagenic (Bythrow 2005). Important vanilla-producing countries include India, Indonesia, Mexico, Papua New Guinea, Puerto Rico, Uganda, and regions of the Indian Ocean, with less-extensive plantations in several equatorial and tropical countries such as Brazil, Colombia, Costa Rica and Australia (Correll 1953, Sasikumar 2010, Havkin-Frenkel & Belanger 2011, Osorio et al. 2012). However, *Vanilla planifolia* has limited genetic variability (Schlüter et al. 2007, Lubinsky et al. 2008a, Minoo et al. 2008), and thus crop wild relatives have been identified as potencial sources of desirable traits for vanilla production, yet field research is needed to better understand their ecology (Nissar et al. 2006, Minoo et al. 2008, Havkin-Frenkel & Belanger 2011, Gigant et al. 2011, Flanagan et al. 2019).

Vanilla comprises about 120 species, with its highest species richness being in Brazil (37 species, 21 of which are restricted to the country) (Pansarin 2010, Ferreira et al. 2017, Flanagan et al. 2019, Flora do Brasil 2020). The informal *V. planifolia* group encompasses 25 taxa, and includes several American species (Soto Arenas & Cribb 2010, Barona-Colmenares 2018, Karremans & Lehamm 2018, Flanagan et al. 2018, 2019). *Vanilla bahiana* is phylogenetically closely related to *Vanilla planifolia* and is restricted to Brazil, where it occurs from Maranhão State to São Paulo State. (Bouetard et al. 2010, Gigant et al. 2011, Villanueva-Viramontes et al. 2017, Flora do Brasil 2020). Regarding the conservation status, *Vanilla bahiana* was recently assessed as 'Endangered' (Ferreira et al. 2017). *Vanilla bahiana* is a deceptive and self-compatible species. It is pollinator dependent, has short anthesis (few hours) at dawn, and low natural fruit set (ca. 2%) (Anjos et al. 2017). However, little is known about its fruit development. High temperatures (> 32ºC), poor ventilation and heavy rain favor fungal infection, and thus are indirectly responsible for fruit drop by *V. planifolia* in cultivation (Hernández-Hernández 2011). The goals of the present study were to (1) follow the process of pod ripening of *V. bahiana* in a restinga fragment in an Environmental Protection Area of Bahia State, and (2) to highlight implications for vanilla crop improvement.

Material and Methods

1. *Study area*

The study was carried out in an area of sand dunes in the Área de Proteção Ambiental de Lagoas e Dunas do Abaeté (APA Abaeté) in the municipality of Salvador (12°54'–12°57'S, 38°18'–38º21'W), northeastern Brazil (Brasil 2018). This protected area was established in 1987 and covers a total of 1,800 hectares (Bahia 1987). The climate is tropical humid, without a dry season (Köppen 1948), and with relative humidity above 70-80% throughout the year (Viana & Kleinert 2005). The annual mean temperature is 25.9 °C, the annual precipitation is 1,885 mm, and April and May are the rainiest months (Schiavone 2014). Distinct restinga phytophysiognomies (*sensu* Brasil, 2009) are found within APA Abaeté, including herbaceous, shrub and restinga forest formations (Britto *et al.* 1993, Silva, 2012).

2. *Data collection*

Fruit development of *V. bahiana* was studied during April 2016 and January 2017 (40 weeks) in a restinga forest fragment bordered by a shrub formation (12°55'S, 38°19'W) and with a discontinuous canopy due to the establishment of trails (Figure 1a). A total of nine manual self-pollinations (SP) and nine manual cross-pollinations (CP) (a single flower per individual) were successfully realized from April 2016 to May 2016. For each raceme, the first flower to open was pollinated (Figure 1b). Pollinations were performed between 08:00 and 08:30 h using all the pollen of the flowers (Anjos et al. 2017). To avoid confusion among treatments, different-colored ribbons were used for each test (Dafni et al. 2005). Fruit lengh (L), diameter (D) and girth (G) was measured every two weeks. Fruit permanence in the infrutescence (F) was measured by counting consecutive days from pollination until the last measurement.

Figure 1. *Vanilla bahiana* Hoehne. (a) Habitat. (b) Intact flower. For each raceme, the first flower to open was pollinated. (c) Immature fruit formed by manual cross-pollination (73 days after pollination; fruit length = 13,2 cm, diameter = 1,1 cm and girth = 4,0 cm). (d) Mature fruit formed by cross-pollination (7 months after pollination; fruit length = 13,1 cm, diameter = 1,1 cm and girth = 4,5 cm). Photographed by Felipe Fajardo V. A. Barberena (a, b) and Tailane Alves do Nascimento (c, d).

3. *Data analysis*

Descriptive statistics, including means, medians, standard deviations, skewness and kurtosis were calculated for the four parameters in order to verify numerically the behavior of the data. Pearson's correlation analysis was used to test the association between pairs of attributes (Callegari-Jacques 2003), and the level of significance for each pair was calculated by Test T. An exploratory analysis of the data was also carried out. Coefficients of variation (CV) for the variables were compared in order to verify the homogeneity of the data around the mean (Pimentel-Gomes 2009). We adopted the following classification for the coefficients of variation (Pimentel-Gomes 2009): low (< 10%), medium (10-20%), high (20-30%), and very high (> 30%). Correlations between all the previously mentioned attributes and temperature (T) and rainfall (R) were also analyzed. Compiled data for temperature and rainfall were obtained from Instituto Nacional de Meteorologia (2018) for the study period. Additional data on reproductive biology of *V. bahiana*, encompasing two flowering seasons (2014/2015 and 2015/2016), were extracted from Anjos et al. (2017).

Results

Fruit maturation is visually evidenced by yellowing and dehiscence of the fruit apex and often occurs about seven months after pollination (up to 217 days after pollination, data not presented) (Figure 1c, d). Regarding the mean of the data, beans formed by manual self-pollination had smaller measurements for length (8.26 *vs* 9.09 cm), girth (2.84 *vs.* 3.12 cm) and diameter (0.84 *vs* 0.87 cm) than fruits formed by manual cross-pollination; coefficients of variation of the three attributes were higher for manual cross-pollination, reflecting the higher means (Table 1 and 2). Similarly, fruit permanence in the infrutescence was longer for cross-pollination than manual-pollination. From the coefficient of variation, a comparison statistic that measures the dispersion of the data around the mean, it was verified that the variation of F was very high for both pollination methods, showing a high degree of variability of the data, which is associated with long permanence. The coefficients of variation for the attributes L, D and C were medium or high for the two pollination methods. These data show that some fruits have more developed morphometric characteristics. Tables 1 and 2 show the descriptive statistics for the attributes according to pollination method.

In self-pollination, fruit length was directly proportional to fruit diameter, girth and permanence, but inversely proportional to rainfall. Girth was directly proportional to fruit diameter and permanence, but inversely proportional to rainfall. Fruit permanence and rainfall were inversely proportional. No statistically significant correlations were recorded between temperature and the morphometric attributes. (Table 3).

In cross-pollination, fruit length was directly proportional to fruit diameter, girth and permanence, but inversely proportional to rainfall. Similarly, fruit diameter was directly related to girth and permanence, and inversely related to rainfall. A significant direct relationship between permanence and girth, and inverse relationships between rainfall and girth and between rainfall and permanence were also recorded. No statistically significant correlations were observed between temperature and the morphometric attributes. (Table 4).

Discussion

Ripening of the fruits of *Vanilla* is essential for obtaining greater amounts of vanillin, and the first month of pod development is a critical phase for *Vanilla planifolia* bean growth (Nissar et al. 2006). For both pollination methods studied longer permanence of the fruit of *Vanilla bahiana* in the infrutescence contributes to increases in all the morphometric attributes studied (except for diameter in manual pollination, for which no correlation was recorded). Plants of restinga experience several limiting conditions such as low water retention and intense sunlight (Rizzini 1997). Although the mean monthly maximum temperature exceeded 32ºC only in January 2017 (Instituto Nacional de Meteorologia 2018), the soil temperature in restinga is much higher, reaching about 50ºC. Nonetheless, individuals of *V. bahiana* occur in shade in the study area and fruit drop does not seem to be correlated with high temperatures. However, higher rainfall was responsible for a significant decrease in the development of fruit length, girth and time of permanence in the infrutescence (fruit drop tends to occur at the beginning of development). Thus, cultivation of *V. bahiana* inside greenhouses can be a strategy to decrease fruit drop, since

Table 1. Descriptive statistics for morphometric attributes and time of permanence for fruit formed by manual self-pollination of *Vanilla bahiana* Hoehne at Área de Proteção Ambiental das Lagoas e Dunas do Abaeté. Attribute: D = diameter; F = time of permanence of the fruit in the infrutescence; G = girth; L = length.

Descriptive statistical measures								
Attribute	**Mean**	**Median**	**Value**		**Standard Deviation**	**Coefficient**		
			Minimum	**Maximum**		**CV(%)**	**Kurtosis**	**Skewness**
D	0.84	0.76	0.60	1.16	0.20	23.6%	-1.20	0.30
F	71.22	40.00	21.00	212.00	74.13	104.1%	0.83	1.60
G	2.84	2.70	2.17	4.10	0.59	20.8%	1.85	1.29
L	8.26	7.70	6.33	11.74	1.77	21.5%	0.73	1.28

Table 2. Descriptive statistics for morphometric attributes and time of permanence for fruit formed by manual cross-pollination of *Vanilla bahiana* Hoehne at Área de Proteção Ambiental das Lagoas e Dunas do Abaeté. Attribute: D = diameter; F = time of permanence of the fruit in the infrutescence; G = girth; L = length.

Descriptive statistical measures								
Attribute	**Mean**	**Median**	**Value**		**Standard Deviation**	**Coefficient**		
			Minimum	**Maximum**		**CV(%)**	**Kurtosis**	**Skewness**
D	0.87	0.80	0.70	1.08	0.16	18.20%	-2.20	0.23
F	114.22	48.00	35.00	213.00	89.59	78.44%	-2.55	0.27
G	3.12	2.86	2.48	3.81	0.55	17.63%	-2.07	0.21
L	9.09	8.18	6.93	12.16	1.89	20.79%	-1.21	0.49

Table 3. Pearson correlation coefficients for environmental variables and morphometric attributes of the fruit of *Vanilla bahiana* Hoehne formed by manual self-pollination at Área de Proteção Ambiental das Lagoas e Dunas. Attribute: D = diameter; F = time of permanence of the fruit in the infrutescence; G = girth; L = length; R = rainfall; T = temperature. ** Significant at 0.01 probability ($p < 0.01$) by the T-Test. * Significant at 0.05 probability ($p < 0.05$) by the T-Test. NS, not significant ($p > 0.05$) by the T-Test.

Attribute	**Correlation Coefficient**					
	D	**F**	**G**	**L**	**R**	**T**
D	1					
F	0.554^{NS}	1				
G	0.861**	0.863**	1			
L	0.765*	0.938**	0.970**	1		
R	-0.458^{NS}	-0.974**	-0.823**	-0.915**	1	
T	-0.530^{NS}	-0.241^{NS}	-0.321^{NS}	-0.263^{NS}	0.130^{NS}	1

Table 4. Pearson correlation coefficients for environmental variables and morphometric attributes of the fruit of *Vanilla bahiana* Hoehne formed by manual cross-pollination at Área de Proteção Ambiental das Lagoas e Dunas. Attribute: D = diameter; F = time of permanence of the fruit in the infrutescence; G = girth; L = Lengh; R = rainfall; T = temperature. ** Significant at 0.01 probability ($p < 0.01$) by the T-Test. * Significant at 0.05 probability ($p < 0.05$) by the T-Test. NS, not significant ($p > 0.05$) by the T-Test.

Attribute	**Correlation Coefficient**					
	D	**F**	**G**	**L**	**R**	**T**
D	1					
F	0.964**	1				
G	0.970**	0.955**	1			
L	0.886**	0.921**	0.920**	1		
R	-0.865**	-0.829**	-0.858**	-0.703*	1	
T	-0.522^{NS}	-0.621^{NS}	-0.504^{NS}	-0.653^{NS}	0.080^{NS}	1

the shading can be administered and the amount of water regulated, benefiting fruit production. In addition, cross-pollination is preferred over self-pollination because of the longer permanence of the fruit in the infrutescence, which also benefits fruit production (see levels of correlation between the variables; Tables 3 and 4).

The formation of natural and artificial hybrids is recurrent in the genus *Vanilla*, and has included taxa native to different continents (Nielsen 2000, Nissar et al. 2006, Minoo et al. 2008, Soto Arenas & Dressler 2010). Hybridization has been exploited to obtain genetic variability and vanilla crop improvement, but is still at an early stage of development (Nissar et al. 2006, Lubinsky et al. 2008b, Sasikumar 2010). The primary desirable traits for vanilla production are high flower production and fruit set, and great resistance to disease and abiotic stress (Soto Arenas 1999). Breeding programs have proven to be efficient, but remain mostly based on species distantly related to *V. planifolia*, when they should involve American species (Soto Arenas & Dressler 2010, Cameron 2011).

Vanilla bahiana presents promising traits that are of value in vanilla crop improvement and may be a good initial choice for new breeding efforts with *V. planifolia*. The species has recently been found to produce significant amounts of vanillin and other compounds related to vanilla flavor (Lopes 2018). In addition, there are other determinant factors to consider: *Vanilla bahiana* has (1) a wide geographical distribution (Ferreira et al. 2017, Flora do Brasil 2020); (2) occurs in different vegetation types and phytogeographic domains – Caatinga and Cerrado, as well as the Atlantic Forest; (3) forms substantial populations in restinga fragments (at least 160 individuals in the study area) – whereas natural populations of several species of *Vanilla* are small (Soto Arenas 1999); (4) is resistant to conditions of drought and high luminosity and temperature; (5) has a long blooming period (over an eight-month period in restinga areas) (Anjos et al. 2017); (6) produces a high number of flowers per raceme – *Vanilla bahiana* bears more flowers than several *Vanilla* species, including *V. planifolia* (up to 31 flowers per inflorescence *versus* 24 flowers) (Childers & Cibes 1948, Anjos *et al.*, 2017); (7) has possible synchronized flowering with *V. planifolia* due to partial overlap of anthesis and pollination times (Soto Arenas 1999, Nissar et al. 2006); and (8) fruits throughout the year (Anjos et al. 2017). Therefore, it may be possible to have flowers, and consequently fruits, throughout the year and over a long period of time (months) for performing vanilla pollination. Furthermore, the adaptations possessed by *V. bahiana* to adverse abiotic factors may favor cropping in areas that are drier and have higher-luminosity, conditions that also reduce the propensity for disease.

These results and prospects are promising and should be further evaluated, not only for *V. bahiana* but for other vanilla crop wild relatives. Experiments with wild species as part of vanilla breeding programs is recommended for growing areas, mainly in tropical and equatorial regions where the most significant plantings are concentrated. Concomitantly, investigation into the reproductive biology of other Brazilian species of *Vanilla* should continue, since studies of pollination ecology can be used to set guidelines for the conservation of the *V. planifolia* group and to encourage the development of strategies to increase the production of fruit and, consequently, vanillin for its culinary uses and medical applications.

Finally, it is necessary to plan appropriate management of genetic resources, including not only the possible reformulation and expansion of vanilla crops, but also *in situ* conservation efforts for the species. Habitat fragmentation is a concern in areas near APA Lagoas e Dunas do Abaeté, as it is in innumerable unprotected areas of Brazil, and may result in rapid population declines of species of *Vanilla*. It is particularly worrying for species threatened with extinction, such as *Vanilla bahiana* and *Vanilla dubia* Hoehne (Menini Neto et al. 2013, Ferreira et al. 2017). The conservation status of the other species of *V. planifolia* group that occur in the country has not been assessed for red lists. Therefore, proper assessment of the conservation status of these species is a necessary next step towards the conservation of the gene pool of *Vanilla*. *Ex situ* conservation actions are also extremely important, and will facilitate research of potential agronomic traits, as well as crop breeding (Flanagan & Mosquera-Espinosa 2016, Flanagan et al. 2019).

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Author Contributions

Tailane Alves do Nascimento: Substantial contribution in the concept and design of the study; contribution to data collection; contribution to manuscript preparation.

Maura da Silva Costa Furtado: Contribution to data analysis and interpretation; contribution to manuscript preparation.

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Felipe Fajardo Villela Antolin Barberena: Substantial contribution in the concept and design of the study; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Short Communication

The surprising "B-side": description of a new foraging tactic for the pearl cichlid, *Geophagus brasiliensis*, in a coastal stream of the Atlantic Forest

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Abstract: A new foraging tactic for the pearl cichlid, *Geophagus brasiliensis*, is described from underwater observations performed in a coastal stream of the Atlantic Forest, Southeastern Brazil. Named "shift picking", the foraging tactic involved the manoeuvering of leaves, wood twigs and tree bark present in the substrate, with fish using its mouth to turn objects and uncover macroinvertebrates adhered to the underside of the object being picked ("B-side"). The object-shifting behaviour is rarely reported for fish and the present description seems to be the first record for a freshwater species of South America.

Keywords: *foraging behaviour; fish ecology; naturalistic studies; Cichlidae; Atlantic Forest.*

O surpreendente "lado-B": descrição de uma nova tática de forrageamento para o acará, *Geophagus brasiliensis*, em um riacho costeiro da Mata Atlântica

Resumo: Uma nova tática de forrageamento do acará, *Geophagus brasiliensis*, é descrita a partir de observações subaquáticas realizadas em um riacho costeiro da Mata Atlântica, Sudeste do Brasil. Chamada de "virar para pegar", a tática de forrageamento envolve o movimento de folhas, galhos e cascas de árvores presentes no substrato, com os peixes usando a boca para virar objetos e expor macroinvertebrados aderidos à parte de baixo dos objetos explorados ("lado B"). O comportamento de mover objetos é raramente relatado e o presente trabalho parece ser o primeiro registro para uma espécie de água doce da América do Sul.

Palavras-chave: *comportamento de forrageamento; ecologia de peixes; estudos naturalísticos; Cichlidae; Mata Atlântica.*

Introduction

The pearl cichlid, *Geophagus brasiliensis* (Quoy & Gaimard, 1824) (Perciformes, Cichlidae), is widely distributed along the coastal drainages of eastern and southern Brazil and Uruguay (Kullander 2003). This species inhabits the lentic habitats and shallow waters of rivers, streams, lakes, reservoirs and even brackish environments (Nunes et al. 2014). Presenting diurnal activity and visual orientation (Sabino & Castro 1990), *G. brasiliensis* feeds on a wide variety of items, preferring benthic resources such as molluscs, vascular plants, crustaceans, fish scales, insects, among others (Nomura & Carvalho 1972, Sabino & Castro 1990, Abelha & Goulart 2004). Its high trophic plasticity and opportunism allow the exploitation of different resources and this species is usually classified as an omnivore (Sabino & Castro 1990, Arcifa & Meschiatti 1993, Dias et al. 2004, Moraes et al. 2004, Gomiero & Braga 2008, Bastos et al. 2011), although differences in prey availability across study sites and conceptual approaches may lead *G. brasiliensis* to a variety of trophic preferences that include detritivory (e.g., Meschiatti 1995), insectivory (e.g., Ribeiro et al. 2014) or even benthivory (e.g., Nunes et al. 2014). However, the diversified foraging behaviour known for *G. brasiliensis* is usually based and inferred from the analysis of stomach contents, thus limiting the understanding of how occurs the ingestion of prey hidden under structures or adhered to objects such as leaves, wood twigs, and tree barks.

Few studies have provided information on the foraging behaviour of *G. brasiliensis* in the wild. Sabino & Castro (1990) observed this species in feeding activity during the day, obtaining food using the foraging tactic named "picking up substrate and sorting prey" (*sensu* Keenleyside

1979), that comprises the combination of the protrusion of the upper jaw with the opening of the operculum to separate the food items from the debris. This foraging behaviour in cichlids has been recently described as "sediment sifting", with several analyses of morphology and evolutionary process related to this strategy for the South American cichlids (see López-Fernández et al. 2012, 2014). Through this tactic, Sabino & Castro (1990) suggested that *G. brasiliensis* was able to excavate the sediment and feed on prey hidden in the substrate. Uieda (1995) also observed the use of this foraging tactic by *G. brasiliensis* and added "picking at relatively small prey" (*sensu* Keenleyside 1979) to the role of foraging tactics displayed by the species. This foraging tactic allowed the species to catch prey on the bottom rocks and classified *G. brasiliensis* as having an intermediate niche amplitude when compared to other two bottom omnivorous fishes which fed on insects (Uieda 1995). After that, no study attempted to refine the knowledge about the feeding behaviour of *G. brasiliensis* through a naturalistic approach, which highlights the need of studies to better understand how prey is selected and captured.

In this study we report a new foraging tactic for *G. brasiliensis*, presumably focusing on macroinvertebrates hidden under objects. We confronted our findings with the literature on the diet of the species, discussing how its morphological and behavioural characteristics can influence the capture of prey. Additionally, we searched for information about the behaviour of moving objects among freshwater fish, since this tactic seems to be rarely described or even uncommon worldwide.

Material and Methods

The study was performed in the Rio das Minas, a coastal stream located in Cananeia, a municipality of Southeastern Brazil that comprises a biodiversity hotspot with the largest remaining fragment of the Atlantic Forest ecosystem in the country (about 24°59'35"S, 48°07'31"W).

The underwater observations were made at day hours (10h00min-14h00min) while snorkelling (*cf.* Sabino 1999), during the dry season between April to August 2018. "Ad libitum" and "behaviour" sampling rules (Martin & Bateson 1986) were used throughout the observational sessions, mostly recorded on a plastic slate. Additionally, digital photographs and video records were taken to check visual observations, based on the methods presented by Sazima (1986) and Sabino (1999). Size estimates (total length in cm, TL) for *G. brasiliensis* were calibrated against objects of known size. Fish identification was done *in situ* during the underwater observations (following Oyakawa et al. 2006 and Oyakawa & Menezes 2011), without the need to capture the animals.

Results

During approximately ten hours of underwater observations, mostly at depths of 0.8 to 2.5 m, 19 individuals of *G. brasiliensis* (8-25 cm TL) were observed moving leaves, wood twigs and fragments of tree bark to uncover prey adhered to the underside ("B-side") of the object being picked (see Supplementary Material - Video). Named here as "shift picking", this foraging tactic started when fish were swimming under organic substrate until they encountered some object (mainly leaves). To turn it, the fish approach the object horizontally, pushing it forward with the mouth while performing movements with the caudal and pectoral fins (Figure 1a). Such movements were apparently stronger when objects were larger in relation to fish size, with fish moving the caudal fin faster than was observed while moving smallest objects. Once turned, the object had the "B-side" explored by the fish; in this case, with fish biting items sighted at the surface of the object, with the body horizontally positioned in relation to the substrate or slightly inclined forward (Figure 1b). Between a bite and another, the fish moved away from the object, swimming backwards and moving the head to the side, in an apparent attempt to spot other prey. The number of bites ranged from one to three per object, with fish performing buccal and opercular movements as described by Sabino & Castro (1990) and Drucker & Jensen (1991) while consuming the prey. The time spent by the fish to turn and examine on each object was about 30 seconds. There was no relationship between the use of "shift picking" and the current flow; however, the foraging tactic was only observed in fish present in lentic environments, such as mesohabitats formed by pools. Although sighted during the observation sessions in the shallower areas of the pools, individuals smaller than 8 cm TL were not observed using this foraging tactic.

Figure 1. *Geophagus brasiliensis* performing "shift picking". The individual on the right side approaches the object (tree bark), turning it with the mouth (a) to pick up a hidden prey (white arrow) (b).

Discussion

Neotropical communities of freshwater fish are characteristically rich in species and present complex interrelationships between its components (Lowe-McConnell 1987). Among these relationships, feeding strategies are known to involve morphological and behavioural specializations, such as cleaning, mimicry and social foraging associations and seem to involve several species of fish and invertebrates (see Sazima 1986 and Sabino et al. 2016 for overviews). However, the manoeuvering of object by freshwater fish (named as "object-shifting behaviour") seems to be uncommon and is poorly documented in the literature.

Available records show that some North American species of the genus *Percina* (family Percinidae) use their conical snout to flip gravel and feed on exposed invertebrates that may be unavailable to other benthic fish (Rosenberger & Angermeier 2003). According to Burkhead (1983) and Jenkins & Burkhead (1993), this behaviour seems to be associated with environments where the substrate is loosely embedded and should not be displayed by young individuals of *Percina* spp. (which live in shallower areas, over sandy substrate). Other records describe the "object-shifting behaviour" for cichlids in Central America (Wisenden et al. 1995 and references therein) and for the coal grunter, *Hephaestus carbo* (Ogilby & McCulloch, 1916) (Terapontidae), in northern Queensland, Australia (Ebner et al. 2018).

In the first case, the cichlids *Amatitlania nigrofasciata* (Günther, 1867), *Cribroheros alfari* (Meek, 1907) and *Cryptoheros panamensis* (Meek & Hildebrand, 1913) were considered as occasional users of two foraging tactics, "fin digging" and "leaf lifting", in an attempt to increase the availability of food for their fry (Wisenden et al. 1995). Sometimes non-breeding individuals of these species occasionally fin dig and leaf lift while foraging for themselves, but both acts appear to be performed more often by breeding pairs, especially when their young are free-swimming fry (Wisenden et al. 1995). In the second case, small (< 5 cm TL) to medium-sized individuals (5-15 cm TL) of *H. carbo* were observed using the mouth, snout and even the nape to lift, flip and roll benthic objects to feed on benthic macroinvertebrates (Ebner et al. 2018). Larger individuals (15-20 cm TL) of *H. carbo* were not observed performing "object-shifting behaviour", which may reflect the ontogenetic changes in the diet of the species, from the ingestion of benthic macroinvertebrates by juveniles to crustaceans, fishes and insects caught in the surface by adults, and/or be related to an effect of data collection (e.g., observer effect) (Ebner et al. 2018).

For *G. brasiliensis*, even though it has been described as an omnivore which consumes a wide range of food items, an analysis of the trophic interactions between the species and the community of benthic macroinvertebrates showed an important contribution of Chironomidae larvae (Diptera) in its diet when compared to other items, especially to debris (Nunes et al. 2014). These findings also suggested that the ingestion of debris and organic matter by *G. brasiliensis* seems to be more related to the selection of macroinvertebrates present in the substrate than to the intentional consumption of this type of item as cited by several studies (Nunes et al. 2014). Our observations of "object-shift behaviour" for *G. brasiliensis* agree with these findings and can help explain the high selectivity of macroinvertebrates (presumably insect larvae such as Chironomidae) by the species.

The non-observation of "shift picking" among individuals of smaller size (< 8 cm TL) may reflect ontogenetic changes in the diet and habitat utilization of *G. brasiliensis*. In the study area, individuals of smaller size preferentially inhabit shallower areas (0.5-0.8 m depth) with predominantly sandy and muddy bottoms, while medium and large-sized individuals (8-25 cm TL) prefer the deeper areas (0.8 to 2.5 m depth) where the foliage covers the bottom (G. R. S. Souza pers. obs.). Thus, the accumulation of allochthonous material allows the concentration of detritivorous invertebrates and may help predict the adoption of "shift picking" by *G. brasiliensis* in coastal streams. The description of this new foraging tactic highlights the importance of naturalistic studies for a better understanding of the way of life of fish in nature and reinforces the importance of the connection between fish and riparian forests in tropical environments. The "object-shifting behaviour" is still rarely reported in the literature for fish and the present description seems to be the first record for a freshwater species in South America.

Supplementary Material

The following online material is available for this article:
Video

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Author Contributions

Gabriel Raposo Silva de Souza: Substantial contributions to the conception and design of the work, contribution to data collection, contribution in the analysis and interpretation of data and contribution in the writing of the work.

José Sabino: Contribution in the analysis and interpretation of data, contribution in the writing of the work and contribution in critical review adding intellectual content.

Domingos Garrone-Neto: Substantial contribution to the idea and design of the work, contribution in analysis and interpretation of data, contribution in the writing of the work and contribution in critical review adding intellectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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