



Myiasis-causing flies in anurans: new interactions, geographic distribution, and an updated list of records in the Neotropics

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Abstract

In this article, we present 34 new cases of myiasis in Neotropical anurans. Of these, 97% were recorded in Brazil, in the morphoclimatic domains of the Amazon, the Cerrado and the Atlantic Forest. A single case was also documented in a rainforest in Costa Rica. The Hylidae family had the highest richness of species affected by myiasis, followed by Leptodactylidae, Bufonidae, Alsodidae, Brachycephalidae, Cycloramphidae, Aromobatidae, Microhylidae and Ranidae. Additionally, from the literature, we compiled a total of 106 records of cases of myiasis affecting anuran species in the Neotropics, including the new records. Our study expands the spectrum of Neotropical anuran species documented as hosts of fly larvae and demonstrates a significant knowledge gap in the ecology of Neotropical anuran species.

Keywords Dipterous parasites · Myiasis in amphibians · Host-parasite

Introduction

Diptera is one of the largest insect orders, with at least 160,000 species described (Courtney et al. 2017). This group is highly diverse in biological and ecological traits, including morphology, habitat use, oviposition behavior, larval development, and life habits (Colless and McApine 1991; Courtney et al. 2009; Courtney and Cranston 2015). Although this order causes negative impacts on agriculture due to its deleterious effects on plants, animals, and human health, larvae and adult flies play important ecological roles in the ecosystems where they occur, acting as predators and prey, pollinators, and scavengers (Courtney et al. 2009). Some dipteran species are responsible for causing myiasis, which is the infestation of fly larvae in living or necrotic tissues of vertebrate hosts

(Zumpt 1965). Human and domestic animals are commonly reported as hosts of fly larvae (Hall and Wall 1995; Stevens et al. 2006; Francesconi and Lupi 2012), but wild animals such as amphibians (D’Bastiani et al. 2020), reptiles (Vanin et al. 2013), birds (Little 2008) and mammals (Foerster et al. 2022) can be infested as well.

Myiasis in anuran amphibians has been reported in the biogeographic regions of Australasia, Indomalaysia, the Nearctic, the Neotropics and the Palearctic (Kraus 2007; Silva et al. 2019; D’Bastiani et al. 2020). These reports involve the fly larvae of several species belonging to the families Calliphoridae, Chloropidae, Phoridae, Muscidae and Sarcophagidae (Zumpt 1965; Bolek and Janovy 2004; Kraus 2007; Arias-Robledo et al. 2019). Taxonomic and ecological information on this parasitic infestation in wild anurans is well-documented in the literature, mainly for the Palearctic realm (Brumpt 1934a, b; Zavadil 1997; Zavadil et al. 1997). In contrast, there is a notable knowledge gap regarding the taxonomy of flies that are capable of causing

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Table 1 New cases of anuran myiasis in the Neotropical region

Anuran hosts		Myiasis-causing fly		Infestation parameters			Infection site	Locality (Country)
Family and species	Stage of life	Family	Species	Ne/Ni (P%)	MI	DR (%)		
Alsodidae								
<i>Limnomedusa macroglossa</i>	A	Undetermined	Undetermined	8/1	NP	NP	Urostyle	Três Barras do Paraná, Paraná (BRA)
Aromobatidae								
<i>Anomaloglossus stepheni</i>	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Back	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)
Brachycephalidae								
<i>Brachycephalus rotenbergae</i>	A	Sarcophagidae	Undetermined	2/2	2	100	Cloaca	Reserva Biológica Serra do Japi, Jundiá, São Paulo (BRA)
Bufonidae								
<i>Dendrophryniscus brevipollicatus</i>	A	Undetermined	Undetermined	1/1	3	100	Ventral and dorsoventral regions	Praia do Puruba, Ubatuba, São Paulo (BRA)
<i>Rhinella marina</i>	T, J	Sarcophagidae	Undetermined	122/13 (10.6)	1	100	Dorsal region	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)
<i>Rhinella ornata</i>	A	Undetermined	Undetermined	4/1	8	Fixed specimen	Ventral and dorsoventral regions	Campo Largo, Paraná (BRA)
<i>Rhinella cf. ornata</i>	A	Undetermined	Undetermined	1/1	NP	100	Oral cavity	Carandá, Minas Gerais (BRA)
<i>Rhinella proboscidea</i>	A	Sarcophagidae	Undetermined	1/1	18	100	Lateral of the head near the eardrum	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)
Hylidae								
<i>Aplastodiscus leucopygius</i>	A	Sarcophagidae	Undetermined	1/1	7	100	Cloaca	São Luiz do Paraitinga, São Paulo (BRA)
<i>Aplastodiscus</i> sp.	A	Undetermined	Undetermined	1/1	NP	NP	Head	Camanducaia, São Paulo, São Paulo (BRA)
<i>Boana cinerascens</i>	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Oral cavity, vocal sac	Distrito de Lindoia, Itacoatiara, Amazonas (BRA)
<i>Boana faber</i>	A	Undetermined	Undetermined	1/1	NP	NP	Posterior region	Parque Estadual do Turvo Derrubadas, Rio Grande do Sul (BRA)
<i>Boana geographica</i>	A	Undetermined	Undetermined	1/1	NP	100	Vocal sac	Presidente Figueiredo, Amazonas (BRA)
<i>Boana leptolineata</i>	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Posterior region	Serra do Faxinal, Cambará do Sul, Rio Grande do Sul (BRA)

Table 1 (continued)

Anuran hosts		Myiasis-causing fly		Infestation parameters			Infection site	Locality (Country)
Family and species	Stage of life	Family	Species	Ne/Ni (P%)	MI	DR (%)		
<i>Boana pulchella</i>	A	Undetermined	Undetermined	1/1	NP	100	Dorsal region	Cidreira, Rio Grande do Sul (BRA)
<i>Bokermannohyla circumdata</i>	A	Undetermined	Undetermined	1/1	NP	NP	Oral cavity, vocal sac	São José dos Pinhais, Paraná (BRA)
<i>Bokermannohyla lylax</i>	A	Undetermined	Undetermined	1/1	NP	NP	Cloaca	Parque Natural Municipal Nascentes de Paranapiacaba, Santo André, São Paulo (BRA)
<i>Bokermannohyla luctuosa</i>	A	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	57	100	Superior and inferior dorsal region	Parque Pico das Cabras, Campinas and Morungaba, São Paulo (BRA)
<i>Bokermannohyla luctuosa</i>	A	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	88	100	Head, dorsal region	Parque Pico das Cabras, Campinas and Morungaba, São Paulo (BRA)
<i>Callinectes tomopterna</i>	A	Undetermined	Undetermined	1/1	NP	NP	Gular region	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)
<i>Scinax</i> sp. (gr. <i>ruber</i>)	A	Sarcophagidae	Undetermined	1/1	10	100	Head, close to the eardrum	Fazenda Experimental da Universidade Federal do Amazonas, Manaus, Amazonas (BRA)
<i>Scinax x-signatus</i>	A	Undetermined	Undetermined	1/1	NP	100	Head, dorsal region	Cotriguaçu, Mato Grosso (BRA)
<i>Smilisca sordida</i>	A	Undetermined	Undetermined	16/1	NP	Fixed specimen	Digestive tube	Águas de Santa Bárbara, São Paulo (BRA)
Leptodactylidae	A	Undetermined	Undetermined	1/1	NP	NP	Right hind leg (thigh)	Santa Rosa, Puriscal, San José (CRI)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Close to the tympanic membrane and the gular region	São José dos Pinhais, Paraná (BRA)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Hind limbs	São José dos Pinhais, Paraná (BRA)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Eardrums	Porto Trombetas, Oriximiná, Pará (BRA)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Anterior dorsal region (right side)	Araguaína, Tocantins (BRA)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Hind limbs	São José dos Pinhais, Paraná (BRA)
	A	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	22	100	NP	Marianópolis, Tocantins (BRA)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Close to the tympanic membrane and the gular region	São José dos Pinhais, Paraná (BRA)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Hind limbs	São José dos Pinhais, Paraná (BRA)
	A	Undetermined	Undetermined	1/1	NP	Fixed specimen	Close to the tympanic membrane and the gular region	São José dos Pinhais, Paraná (BRA)

Table 1 (continued)

Anuran hosts		Myiasis-causing fly		Infestation parameters			Locality (Country)
Family and species	Stage of life	Family	Species	Ne/Ni (P%)	MI	DR (%)	
<i>Leptodactylus rhodomystax</i>	A	Undetermined	Undetermined	1/1	1	Fixed specimen	Fazenda São Nicolau, Cotriguaçu, Mato Grosso (BRA)
<i>Leptodactylus sertanejo</i>	A	Undetermined	Undetermined	43/1 (2.3)	NP	Fixed specimen	Águas de Santa Bárbara, São Paulo (BRA)
Microhylidae							
<i>Elachistocleis surinamensis</i>	A	Sarcophagidae	<i>Lepidodexia (Notochaeta)</i> sp.	1/1	NP	NP	Parque Nacional do Viruá, Caracaraí, Roraima (BRA)
Ranidae							
<i>Aquarana catesbeiana</i>	A	Undetermined	Undetermined	1/1	NP	100	Jaraguá do Sul, Santa Catarina (BRA)

The life stage of anuran hosts: A – adult, J – juvenile, T tadpole. **Infestation parameters:** Ne number of examined hosts, Ni number of infested hosts, P% prevalence in percentage, MI mean intensity, DR death rate, SI site of larva infestation, NP not provided. **Countries:** BRA Brazil, CRI Costa Rica

myiasis in anurans and the biology of these relationships in the Neotropics. Most reports of myiasis in Neotropical anurans are the result of occasional observations, recorded mainly in Brazil, that are published as short notes that describe the damage caused by Sarcophagidae larvae but do not provide the identity of the myiasis-causing flies (Silva et al. 2019; D’Bastiani et al. 2020).

Two recent reviews have summarized reports of myiasis in Neotropical anurans. A case report of a fly larvae infestation in the hylid *Trachycephalus typhonius* (Linnaeus, 1758) by Silva et al. (2019) aimed to provide a summary list of many reports of myiasis in anurans, but the authors did not include some of the reports that were published in gray and hard-to-find literature. In addition, D’Bastiani et al. (2020) presented new reports of myiasis in anurans from the Atlantic Forest of southern Brazil, together with the information available in the literature on myiasis caused by the family Sarcophagidae in Neotropical anurans. Since the last published work, a notable number of new cases of myiasis in anurans, as yet unpublished, have been recorded by us during field surveys, as well as occasional observations conducted between 1991 and 2022. To date, these reports remain unpublished. Therefore, summarizing the current knowledge regarding the interactions between myiasis-causing flies and Neotropical anurans using the information available in the literature and unpublished reports is essential in order to have a more complete view of the anuran species affected by myiasis in the region. Thus, the objectives of this study are (1) to record new cases of myiasis in Neotropical anurans, (2) to gather and synthesize existing records of the interaction between anurans and myiasis-causing flies and (3) to outline the geographic distribution of the reports of myiasis in the Neotropical region.

Materials and methods

Collection and examination of anuran hosts

New cases of myiasis in Neotropical anurans were documented from an accidental encounter of specimens affected by dipteran larvae in the field, with photographic records and/or collection; photographic records with observation data, but without specimen collection; and encounters of specimens affected by myiasis deposited in scientific collections of public universities or research institutes between 1991 and 2022.

During field studies conducted between 2010 and 2021, anurans affected by myiasis were collected and transported to the laboratory. These were kept in favorable conditions until adult flies were obtained, and subsequent taxonomic identification was carried out (Table 1). For these records, we provide detailed information on the hosts and the



Fig. 1 Biogeographic regionalization map showing the distribution of the cases of anuran myiasis in the Neotropical region. Black dots represent literature records. Yellow dots represent new cases provided in this study. Countries with occurrence records of anuran myiasis (ARG – Argentina; BRA – Brazil; COL – Colombia; CRI – Costa Rica;

GUY – Guyana; MEX – Mexico; NIC – Nicaragua; PAN – Panama; PER – Peru; TTO – Trinidad and Tobago; VEN – Venezuela). The map is based on the modified shapefiles of the biogeographic regionalization of Morrone et al. (2022)

myiasis-causing flies (family and species), the parasitological parameters of infestation (prevalence, mean infestation intensity, mortality rate and larval infestation site) (Bush et al. 1997) and the location of the record (locality and country).

The taxonomic nomenclature of Amphibia follows Frost (2025) and the nomenclature of Diptera follows the updated database of the Departamento de Entomologia, Museu Nacional, Universidade Federal do Rio de Janeiro (UFRJ), Brazil, and the Coordenação de Zoologia, Museu

Paraense Emílio Goeldi (MPEG), which were monitored by the authors CMP and FSCF.

Bibliographic review

We conducted a bibliographic search for the years between 2018 and 2024, using Google Scholar to update the list of interactions between anuran hosts and myiasis-causing flies in the Neotropical region that was created by Silva et al. (2019) and D’Bastiani et al. (2020). The search terms used were: “myiasis”, “mifase”, “amphibians”, “anfíbios”, “anurans” and “anuros”. Additionally, we searched for natural history notes published in *Acta Biologica Colombiana*, *Caribbean Herpetology*, *Caldasia*, *Cuadernos de Herpetología*, *Herpetological Bulletin*, *Herpetological Review*, *Herpetology Notes*, *Mesoamerican Herpetology*, *North-Western Journal of Zoology*, *Revista Latinoamericana de Herpetología*, and *Reptiles & Amphibians*. We extracted information regarding the host, fly species and study location (locality and/or country) from the myiasis cases that were reviewed. Scientific names of the hosts were updated to the current taxonomy following Frost (2025) | *Amphibian Species of the World 6.2*, an Online Reference (<https://amphibiansoftheworld.amnh.org/index.php>) for anurans, and Evenhuis and Pape (2024) | *Systema Dipteriorum: The Biosystematic Database of World Diptera* (<http://www.diptera.org/>) for flies.

Results

New cases of myiasis in Neotropical anurans

We recorded 34 new cases of myiasis in Neotropical anurans. Of these, 97% ($n=33$) were recorded in Brazil, with a single record for Costa Rica, which were distributed in 31 species (Table 1, Fig. 1). The family Hylidae had the highest number of species affected by myiasis ($n=14$ species), followed by Leptodactylidae ($n=8$), Bufonidae ($n=5$) and Alsodidae, Brachycephalidae, Cycloramphidae, Aromobatidae, Microhylidae and Ranidae ($n=1$ each) (Fig. 2). We observed myiasis more frequently ($n=33$) in adult anurans than in juveniles or tadpoles ($n=1$) (Stage of life 42) (Gosner 1960). In 26 cases, the flies causing myiasis were not identified at the family or species levels. In the remaining eight cases, we identified the fly family ($n=4$), the fly genus ($n=1$) or the fly species ($n=3$). For six cases in which specimens affected by myiasis were collected, we describe the collection and examination of the infested hosts, as well as the entomological procedures in the laboratory used to obtain adult flies for identification (Table 2, Figs. 3, 4, 5 and 6).

Fig. 2 Anuran species found with myiasis (black arrows indicate sites infested with larvae or eggs). **1** General view and **1'** close-up view of *Limnomedusa macroglossa* (Duméril and Bibron, 1841), **2** *Brachycephalus rotenbergae* Nunes, Guimarães, Moura, Pedrozo, Moroti, Castro, Stuginski, and Muscat, 2021, **3** *Dendrophryniscus brevipollicatus* Jiménez de la Espada, 1870, **4** *Rhinella marina* (Linnaeus, 1758), **5** *Rhinella ornata* (Spix, 1824), **5'** *Rhinella* cf. *ornata*, **6** general view and **6'** *Rhinella proboscidae* (Spix, 1824), **7** *Anomaloglossus stepheni* (Martins, 1989), **8** *Aplastodiscus leucopygius* (Cruz & Peixoto, 1985), **9** *Aplastodiscus* sp., **10** *Boana cinerascens* (Spix, 1824), **11** general view of *Boana faber* (Wied-Neuwied, 1821). Photos by Rodrigo Lingnau (1, 1'), Alexandre Poletini Neto (2), César Alexandre (3), Franciele C. Souza (4, 6, 6'), Vinicius Guerra (5), Rodrigo G. Tinoco (5'), Domingos de J. Rodrigues (7), Célio F. B. Haddad (8), Webysther Nunes (9), Robson W. Ávila (10), and Bjørn-Einar Nilsen (11). Anuran species found with myiasis (black arrows indicate sites infested with larvae or eggs). **12** General view and **12'** close-up view of *Boana geographica* (Spix, 1824), **13** *Boana leptolin-eata* (Braun & Braun, 1977), **14** *Boana pulchella* (Duméril & Bibron, 1841), **15** general view and **15'** close-up view of *Bokermannohyla circumdata* (Cope, 1871), **16** *Bokermannohyla hylax* (Heyer, 1985), **17** general view, and **17'/17''** close-up view of *Bokermannohyla luctuosa*, **18** *Scinax* sp. (gr. *ruber*) from Cotriguaçu, Mato Grosso, **9** *Scinax* sp. (gr. *ruber*) from Manaus, Amazonas, **20** *Scinax x-signatus* (Spix, 1824). Photos by Alexandre Almeida (12, 12'), Milena Wachlewski (13), Célio F.B. Haddad (14), André Luiz F. da Silva (15, 15'), Cauê R. Reis (16), Victor M. Ghirotto (17, 17', 17''), Domingos de J. Rodrigues (18), Franciele C. Souza (19), and Márcio Martins (20). Anuran species found with myiasis (black arrows indicate sites infested with larvae or eggs). **21** General view and **21'** close-up view of *Smilisca sordida* (Peters, 1863), **22** *Callimedusa tomopterna* (Cope, 1868), **23** *Adenomera andreae* (Müller, 1923), **24** *Adenomera* sp.1, **25** *Adenomera* sp. 2, **26** *Leptodactylus rhodomystax* Boulenger, 1884, **27** close-up view of *Leptodactylus sertanejo* Giaretta & Costa, 2007, **28** dorsal view and **28'** ventral view of *Physalaemus cuvieri* Fitzinger, 1826, **29** *Physalaemus lateristriga* (Steindachner, 1864), **30** general view of *Elachistocleis surinamensis*, **30'** larval stage (pupae) of myiasis-causing fly from *E. surinamensis*, **31** general view and **31'** close-up view of *Aquarana catesbeiana* (Shaw, 1802). Photos by Allen Lara González (21, 21'), Marcelo Gordo (22, 30, 30'), Leandro O. Drummond (23), Sílioniã P. Dantas (24), André Luiz F. da Silva (25, 28, 28', 29), Domingos de J. Rodrigues (26), Márcio Martins (27), and Ângelo Tafner (31, 31')

Bibliographic review

We compiled a total of 106 records of myiasis affecting amphibians in the Neotropics, including 34 new records for Brazil (33) and Costa Rica (1) (Table 1). We identified 14 studies regarding Neotropical anurans affected by myiasis that were published between 1990 and 2022, which were not included in previous reviews. These studies report 23 cases of myiasis affecting 18 different anuran species, distributed in four families: Bufonidae, Brachycephalidae, Dendrobatidae and Hylidae (Table 3).

Geographic distribution

Cases of myiasis in anurans from the Neotropical region have been reported in Argentina, Brazil, Colombia, Costa Rica,



Mexico, Nicaragua, Panama, Peru, Trinidad and Tobago, and Venezuela (Fig. 1; Table 3). These cases were distributed in the following biogeographic regions: Mexican transition zone, Brazilian subregion/Mesoamerican domain, Pacific domain, Boreal Brazilian domain, South Brazilian domain, Chacoan

subregion/Southeastern Amazonian domain, Chacoan domain, and Paraná domain (Fig. 1). A high concentration of cases of myiasis occurred in the Atlantic Forest in the Paraná domain in southern and southeastern Brazil (Fig. 1). In the Amazon rainforest, there was also a concentration of cases in the South



Fig. 2 (continued)

Brazilian domain and in the Boreal Brazilian domain in northern Brazil (Fig. 1). Scattered cases were recorded in the Paraná domain in Argentina and Brazil; Chacoan and South Brazilian domains and Chacoan subregion/Southeastern Amazonian domain in central and northern Brazil; Boreal Brazilian

domain; Pacific domain in Trinidad and Tobago, Venezuela, Colombia, Panama, and Costa Rica; Mexican transition zone and Brazilian subregion/Mesoamerican domain in Nicaragua and Mexico (Fig. 1).

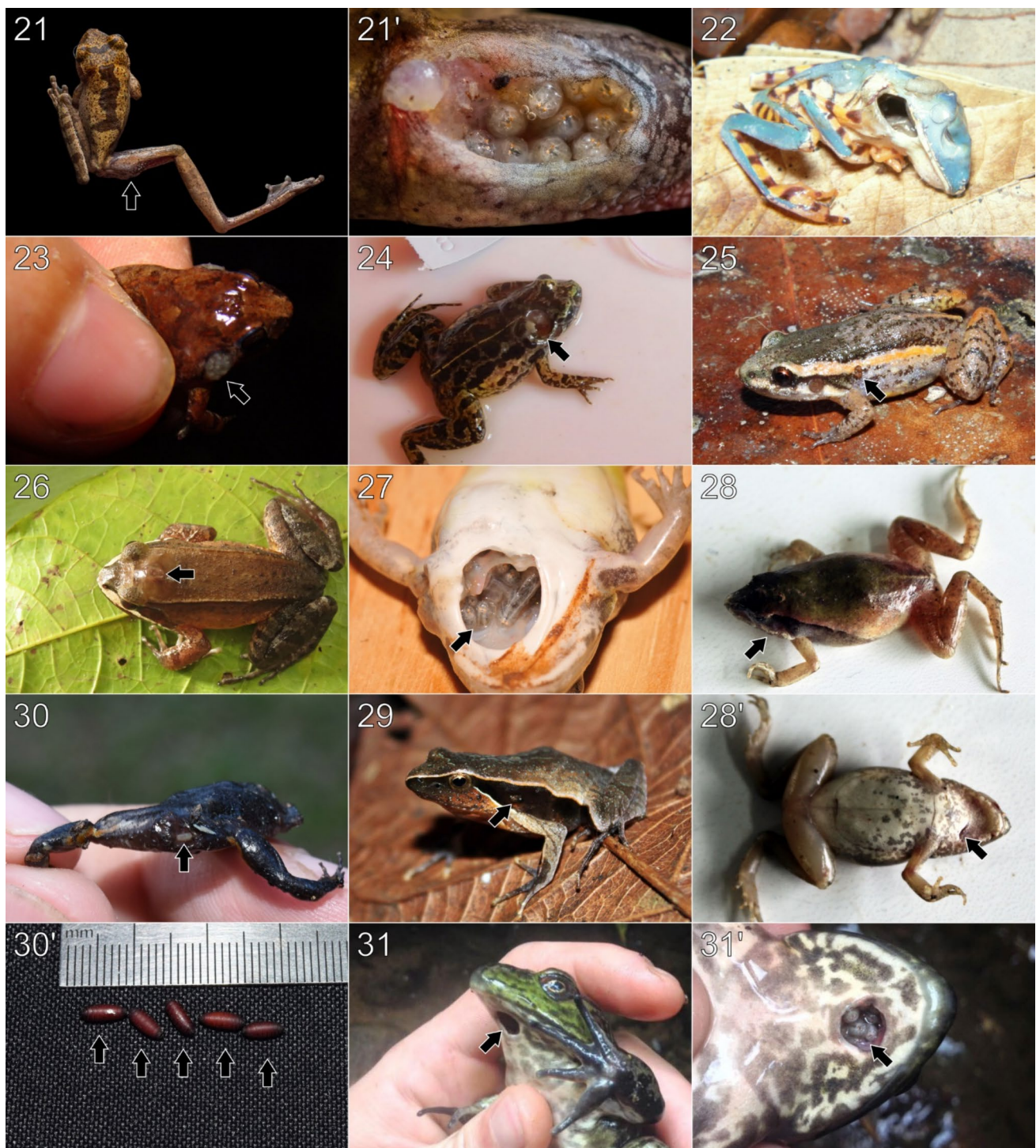


Fig. 2 (continued)

Table 2 Data for specimens of anurans affected by myiasis, collected during field studies and kept in the laboratory to obtain adult flies

Anuran hosts		Myiasis-causing fly		Infestation parameters			Locality (country)	
Family and species	Stage of life	SVL (mm)	Family	Species	Ne/Ni (P%)	MI	Death rate (%)	Hatching of adults
Infection site								
Habitat/ Substrate								
Year								
Bufonidae								
<i>Rhinella marina</i>	T, J	10	Sarcophagidae	Unidentified ¹	122/13 (10.6)	1	100	Only larvae and pupae
								Dorsal region
								Sandy soil
								2016
								Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)
Hylidae								
<i>Bokermannohyla luctuosa</i>	A	85	Sarcophagidae	<i>Lepidodexia</i> (<i>Notochaeta</i>) <i>bufonivora</i> ²	1/1 (NA)	57	100	11 days
								Dorsal region, left side, behind head
								Vegetation
								2019
								Reserva Biológica Serra do Japi, Jundiá, São Paulo (BRA)
<i>Bokermannohyla luctuosa</i>	A	90	Sarcophagidae	<i>Lepidodexia</i> (<i>Notochaeta</i>) <i>bufonivora</i> ²	1/1 (NA)	88	100	12 days
								Dorsal region, left side, in head, behind eye
								Vegetation
								2020
								Reserva Biológica Serra do Japi, Jundiá, São Paulo (BRA)
<i>Scinax</i> sp. (gr. <i>ruber</i>)	A	65	Sarcophagidae	Unidentified ¹	1/1 (NA)	10	100	8 days
								Gular region
								Calycey soil
								2022
								Fazenda Experimental da UFAM, Manaus, Amazonas (BRA)
Leptodactylidae								
<i>Leptodactylus fuscus</i>	A	42	Sarcophagidae	<i>Lepidodexia</i> (<i>Notochaeta</i>) <i>bufonivora</i> ³	1/1 (NA)	22	100	15 days
								Head, dorsal region
								NP
								2021
								Marianópolis, Tocantins (BRA)
Microhylidae								
<i>Elachistocleis surinamensis</i>	A	25	Sarcophagidae	<i>Lepidodexia</i> (<i>Notochaeta</i>) sp. ⁴	1/1 (NA)		100	14 days
								Posterior of the left thigh, close to the cloaca
								NP
								2017
								Parque Nacional do Virá, Caracará, Roraima (BRA)

Abbreviations: T tadpole, J juvenile, A adult, SVL snout-vent length, Ne number of examined hosts, Ni number of infested hosts, P% prevalence in percentage, MI mean intensity, NP Not provided

¹In the process of being listed by Laboratório de Parasitologia, Instituto Nacional de Pesquisas da Amazônia, INPA² Célio F. B. Haddad Amphibian Collection, Universidade Estadual “Júlio de Mesquita Filho”, UNESP Rio Claro (n° MZ053461; MZ053463; MZ053464; Host: CFBH: 44509)³ In the process of being listed by Laboratório de Diptera – Sarcophagidae, Museu Nacional da Universidade Federal do Rio de Janeiro, UFRJ⁴ Museu Paraense Emílio Goeldi Universidade Federal do Pará, UFPA (n° MPEG 02032642)

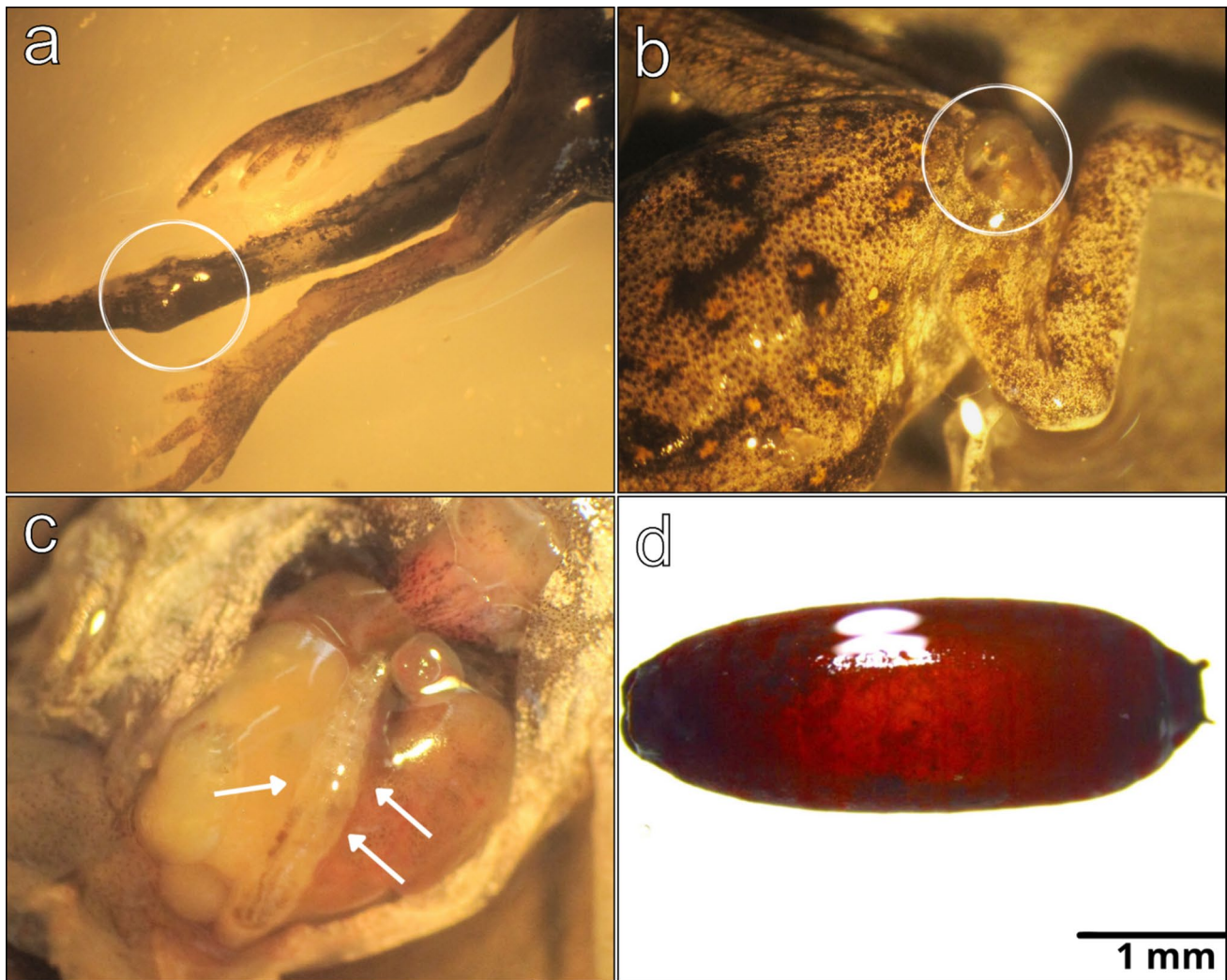


Fig. 3 Fly larvae recorded in tadpoles and juveniles of *Rhinella marina*, collected in the Reserva Florestal Adolpho Ducke, municipality of Manaus, Amazonas state, northern Brazil. **a** Larva encysted on the tail of a tadpole of *R. marina*, **b** larvae feed on a juvenile of *R.*

marina, at the same time their spiracles remain in contact with the external environment performing gas exchange, **c** larva feeding on the internal organs of a juvenile *R. marina*, **d** pupal stage belonging to Sarcophagidae. Photos by Franciele C. Souza

Discussion

New interactions between anurans and myiasis-causing flies

We present a significant number of new cases of myiasis in Neotropical anurans, with several records for Brazil and one single one for Costa Rica. However, the fly could only be identified in four of them, including *Lepidodexia (Notochaeta) bufonivora* (Lopes & Vogelsang, 1953) (Sarcophagidae) parasitizing *Bokermannohyla*

luctuosa (Pombal & Haddad, 1993) (Hylidae) (Lemos et al. 2019) and *Leptodactylus fuscus* (Schneider, 1799) (Leptodactylidae) (Alcantara et al. 2015). *Bokermannohyla luctuosa* was previously reported as a host of a fly, with undetermined identification, in the state of Paraná, Brazil (Lemos et al. 2019). *Leptodactylus fuscus*, on the other hand, was reported as a host of two species of flies (Phoridae): *Megaselia scalaris* (Loew, 1866) and *Oxysarcodexia carvalhoi* Lopes, 1946 in the state of Mato Grosso do Sul, Brazil (Alcantara et al. 2015) and of an undetermined species in the state of São Paulo, Brazil (Paredero et al.

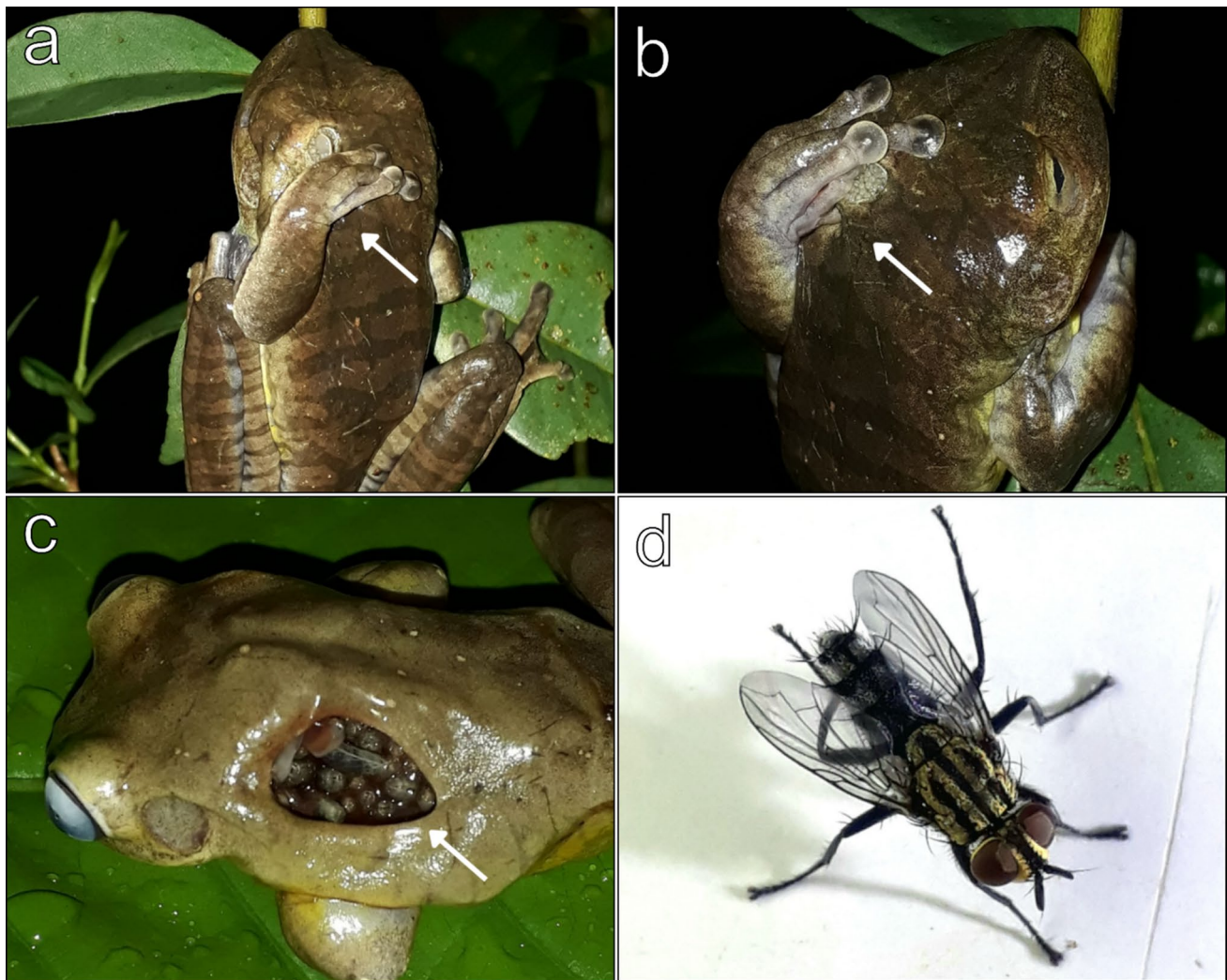


Fig. 4 Defensive behavior of an adult *Bokermannohyla luctuosa* to remove *Lepidodexia (Notochaeta) bufonivora* larvae from the cutaneous lesion on its head. **a, b** The anuran moving its left hand repeatedly from top to bottom over the lesion trying to remove the larvae from the wound, **c** larvae of *L. (N.) bufonivora* inside the cutaneous

lesion feeding on the tissues and body fluids of the dead treefrog, **d** adult individual of the fly *L. (N.) bufonivora* reared in the laboratory. Photos by Victor M. Ghirotto (a, b, c), and Pedro Álvaro B.A. Neves (d)

2017). We recorded, for the first time, the occurrence of flies of the genus *Lepidodexia (Notochaeta)* sp. infesting a fossorial specimen, *Elachistocleis surinamensis* (Daudin, 1802), which is an unprecedented record for the family Microhylidae in the Amazon region. Case reports of myiasis in anurans are often the result of occasional observations made by herpetologists, who publish these reports as short communications with little taxonomic and biological information about fly-anuran larval interactions, partly due to infrequent collaborations with specialists, such as entomologists or parasitologists (Mulieri et al. 2018; Vazquez-Corzas et al. 2018). In most of the cases presented here,

the fly species were not identified. However, 21 of the 34 cases of myiasis are reported as novel hosts of fly larvae.

Current knowledge on myiasis in Neotropical anurans

Reports of myiasis in anurans are widely distributed in the Neotropical region, with most cases having been recorded in Brazil (Silva et al. 2019; D’Bastiani et al. 2020). The remarkable number of records of myiasis in anurans concentrated in the Atlantic Forest in the Paraná domain in southern and southeastern Brazil may be related to a high species

Fig. 5 Adult *Scinax* sp. (gr. *ruber*) with larvae of myiasis-causing fly, collected in the Fazenda Experimental of the Universidade Federal do Amazonas, municipality of Manaus, Amazonas state, northern Brazil. **a, b** Larvae inside the cutaneous lesion in the cephalic region, close to the eardrum, **c, d** female flies identified as belonging to Sarcophagidae. Photos by Silionamã P. Dantas (a, b), Matheus M.M. Soares, and Fernando S. Carvalho-Filho (c, d)

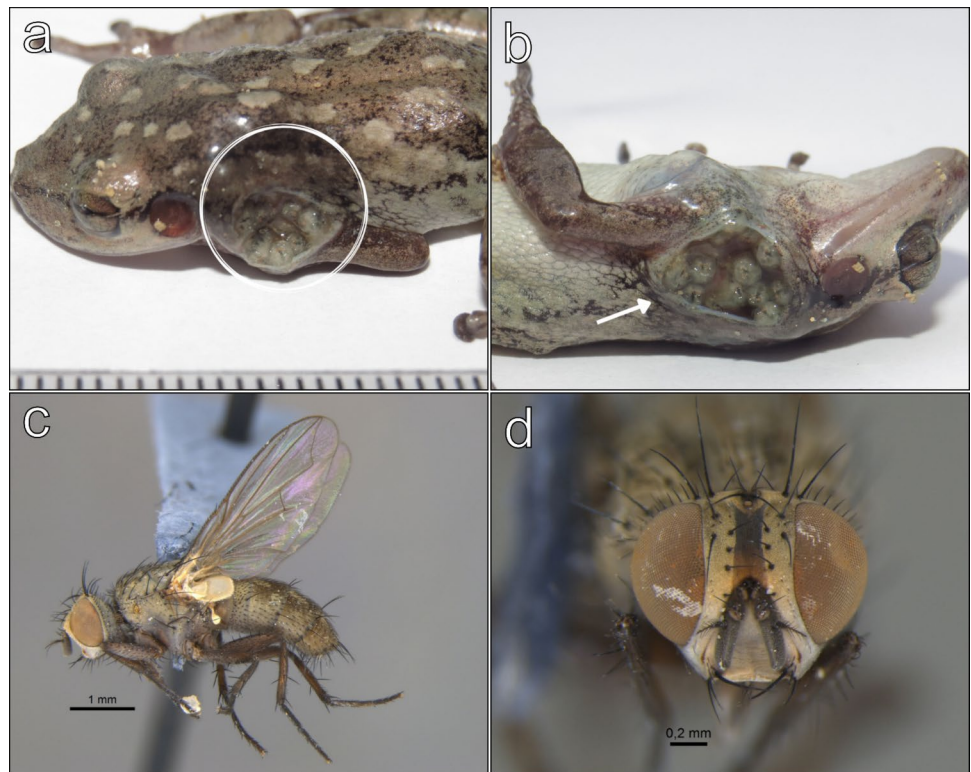


Fig. 6 Adult *Elachistocleis surinamensis* infested with larvae of myiasis-causing fly, collected in the Parque Nacional do Viruá, municipality of Caracará, Roraima state, northern Brazil. **a** Larvae inside the cutaneous lesions on the left hind limb and cloaca, **b** container with the pupated larvae, **c, d** adult fly identified as *Lepidodexia* (*Notochaeta*) sp. Photos by Marcelo Gordo (a, b), Matheus M.M. Soares, and Fernando S. Carvalho-Filho (c, d)



richness and greater research efforts than in other Neotropical ecoregions (Van Noorden 2014; D’Bastiani et al. 2020), a pattern that also was observed in the Amazon rainforest

in Peru and northern Brazil. The Atlantic Forest is one of the world’s 36 most biodiverse hotspots (Mittermeier et al. 2011; Noss et al. 2015), and it harbors more than 40% (625

Table 3 Anuran species recorded as hosts of fly larvae in the Neotropical region

Host family and species	Myiasis-causing fly		Infested hosts Ne/Ni (P%)	Location (country)	References
	Family	Species			
Alsodidae					
<i>Limnomedusa macroglossa</i>	Undetermined	Undetermined	8/1	Rio Guarani, Três Barras do Paraná, Paraná (BRA)	Present study
Aromobatidae					
<i>Anomaloglossus stepheni</i>	Undetermined	Undetermined	1/1	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)	Present study
Brachycephalidae					
<i>Brachycephalus rotenbergae</i>	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	2/2	Atibaia, São Paulo (BRA)	Sebben and Schwartz (1992)
	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Cofia, São Paulo (BRA)	Schwartz and Sebben (1992)
	Sarcophagidae	Undetermined	2/2	Serra do Japi, Jundiá, São Paulo (BRA)	Present study
<i>Iscnocnema henselii</i> (Peters, 1870)	Sarcophagidae	Undetermined	28/1 (3.6)	Área de Proteção Ambiental Guaraqueçaba, Paraná (BRA)	D’Bastiani et al. (2020)
Craugastoridae					
<i>Craugastor rhodopsis</i> (Cope, 1867)	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Coatepec, Veracruz (MEX)	Vázquez-Corzas et al. (2018)
Eleutherodactylidae					
<i>Eleutherodactylus</i> sp.	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Barro Colorado island (PAN)	Dodge (1968)
Bufo					
<i>Atelopus varius</i> (Lichtenstein & Martins, 1856)	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	751/40 (5.3)	Santa Elena, Puntarenas (CRI)	Crump and Pounds (1985)
<i>Dendrophryniscus brevipollicatus</i>	Undetermined	Undetermined	1/1	Praia do Puruba, Ubatuba, São Paulo (BRA)	Present study
<i>Rhinella alata</i> (Thomiot, 1884)	Sarcophagidae	Undetermined	5/5	Gamboia, Colón (PAN)	Kelehear et al. (2020)
	Sarcophagidae	Undetermined	256/3 (1.2)	Masambi, Panama (PAN)	Kelehear et al. (2020)
<i>Rhinella diptycha</i> (Cope, 1862)	Calliphoridae	<i>Lucilia eximia</i> (Wiedemann, 1819)	1/1	Botucatu, São Paulo (BRA)	Jim (1990)
	Sarcophagidae	<i>Peckia (Sarcodexia) lambens</i> (Wiedemann, 1830)	1/1	Brasília, Distrito Federal (BRA)	Ledo et al. (2012)
<i>Rhinella margaritifera</i> (Laurenti, 1768)	Sarcophagidae	Undetermined	3/3	Sabará, Minas Gerais (BRA)	de Souza-Pinto et al. (2015)
	Undetermined	Undetermined	1/1	Portel, Pará (BRA)	Carvalho-Filho et al. (2010)
<i>Rhinella marina</i>	Sarcophagidae	<i>Lepidodexia (Notocheata)</i> sp.	136/2 (1.5)	Northern Trinidad (TTO)	Burgon et al. (2012)
	Sarcophagidae	Undetermined	122/13 (10.6)	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)	Present study
<i>Rhinella nattereri</i> (Bokermann, 1967)	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Rancho Grande, Aragua (VEN)	Lopes and Vogelsang (1953)

Table 3 (continued)

Host family and species	Myiasis-causing fly		Infested hosts Ne/Ni (P%)	Location (country)	References
	Family	Species			
<i>Rhinella ornata</i>	Phoridae	<i>Megaselia scalaris</i>	1/1	Puerto Igazú, Misiones (ARG)	López (2019)
	Sarcophagidae	Undetermined	39/3	Área de Proteção Ambiental Guaraqueçaba (BRA)	D’Bastiani et al. (2020)
<i>Rhinella cf. ornata</i>	Undetermined	Undetermined	4/1	Campo Largo, Paraná (BRA)	Present study
<i>Rhinella proboscidea</i>	Undetermined	Undetermined	1/1	Carandaí, Minas Gerais (BRA)	Present study
	Undetermined	Undetermined	1/1	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)	Present study
Centrolenidae					
<i>Teratohyla pulverata</i> (Peters, 1873)	Sarcophagidae	Undetermined	1/1	Reserva Privada Refugio Bartola, Río San Juan (NIC)	Salazar-Saavedra et al. (2017)
<i>Hyalinobatrachium fleischmanni</i> (Boettger, 1893)	Sarcophagidae	Undetermined	1/1	Parque Nacional Soberanía, Colón and Panama (PAN)	Medina et al. (2009)
Dendrobatidae					
<i>Ameerega bassleri</i> (Melin, 1941)	Undetermined	Undetermined	1/1	Central Alto Caynarachi Valley (PER)	Hagman et al. (2005)
	Undetermined	Undetermined	1/1	Chumilla River, Huallaga (PER)	Hagman et al. (2005)
	Undetermined	Undetermined	1/1	West Flank, Uruhuasha (PER)	Hagman et al. (2005)
	Undetermined	Undetermined	1/1	South Carrachamera (PER)	Hagman et al. (2005)
	Undetermined	Undetermined	1/1	Upper Alto Caynarachi Valley (PER)	Hagman et al. (2005)
<i>Ameerega cainarachi</i> (Schulte, 1989)	Sarcophagidae	Undetermined	1/1	Chumilla River, Huallaga (PER)	Hagman et al. (2005)
<i>Ameerega trivittata</i> (Spix, 1824)	Undetermined	Undetermined	1/1	Yurimaguas road (at 6 km) (PER)	Hagman et al. (2005)
	Undetermined	Undetermined	~20/~10 (50.0)	Chumilla River, Huallaga (PER)	Hagman et al. (2005)
	Sarcophagidae	<i>Peckia (Sarcodeixia) lambens</i>	1/1	Yurimaguas road (at 34 km) (PER)	Hagman et al. (2005)
<i>Dendrobates tinctorius</i> (Cuvier, 1797)	Phoridae	<i>Megaselia scalaris</i>	1/1	NP	Zwart et al. (2005)
<i>Ranitomeya uakari</i> (Brown, Schulte & Summers, 2006)	Undetermined	Undetermined	1/1	Madre Selva Biological Station, Loreto (PER)	von May et al. (2019)
Hylidae					
<i>Aplastodiscus arildae</i> (Cruz & Peixoto, 1987)	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	2/2	Teresópolis, Rio de Janeiro (BRA)	Eizemberg et al. (2008)
<i>Aplastodiscus leucopygius</i> (Cruz & Peixoto, 1985)	Sarcophagidae	Undetermined	1/1	São Luiz do Paraitinga, São Paulo (BRA)	Present study
<i>Aplastodiscus</i> sp.	Undetermined	Undetermined	1/1	Camanducaia, São Paulo, São Paulo (BRA)	Present study
<i>Agalychnis saltator</i> Taylor, 1955	Undetermined	Undetermined	1/1	Reserva de la Biósfera Bosawas, Jinotega (NIC)	Travers and Townsend (2010)
<i>Boana atlantica</i> (Caramaschi & Velosa, 1996)	Sarcophagidae	Undetermined	2/2	Igrapiúna, Bahia (BRA)	Oliveira et al. (2012)

Table 3 (continued)

Host family and species	Myiasis-causing fly		Infested hosts Ne/Ni (P%)	Location (country)	References
	Family	Species			
<i>Boana beckeri</i> (Caramaschi & Cruz, 2004)	Sarcophagidae	<i>Lepidodexia (Notochaeta) centenaria</i> Mello Patiu and Luna, 2010	1/1	Conceição das Pedras, Minas Gerais (BRA)	Mello-Patiu and de Luna-Dias (2010)
<i>Boana caingua</i> (Carrizo, 1991)	Sarcophagidae	<i>Lepidodexia (Notochaeta) centenaria</i>	4/4	Pedralva, Minas Gerais (BRA)	Mello-Patiu and de Luna-Dias (2010)
<i>Boana cinerascens</i>	Phoridae	<i>Megaselia scalaris</i>	1/1	Puerto Iguazú, Misiones (ARG)	López et al. (2016)
	Undetermined	Undetermined		Distrito de Lindaia Itacoatiara, Amazonas (BRA)	Present study
<i>Boana curupi</i> (Garcia, Faivovich & Haddad, 2007)	Undetermined	Undetermined	1/1	San Pedro, Misiones (ARG)	López and Nazer (2009)
<i>Boana faber</i>	Phoridae	<i>Megaselia scalaris</i>	3/3	Puerto Iguazú, Misiones (ARG)	López (2019)
	Undetermined	Undetermined	1/1	Parque Estadual do Turvo Derrubadas, Rio Grande do Sul (BRA)	Present study
<i>Boana geographica</i>	Undetermined	Undetermined	1/1	Presidente Figueiredo, Amazonas (BRA)	Present study
<i>Boana latistriata</i> (Caramaschi & Cruz, 2004)	Calliphoridae	Undetermined	1/1	Campos do Jordão, São Paulo (BRA)	Gomes et al. (2018)
<i>Boana leptolineata</i>	Undetermined	Undetermined	1/1	Serra do Faxinal, Cambará do Sul, Rio Grande do Sul (BRA)	Present study
<i>Boana pulchella</i>	Undetermined	Undetermined	1/1	Cidreira, Rio Grande do Sul (BRA)	Present study
<i>Boana stenocephala</i> (Caramaschi & Cruz, 1999)	Calliphoridae	<i>Lucilia</i> or <i>Hemilucilia</i>	1/1	Cristina, Minas Gerais (BRA)	Gomes et al. (2018)
<i>Boana semiguttata</i> (Lutz, 1925)	Sarcophagidae	Undetermined	5/3	Parque Estadual Pico do Marumbi, Paraná (BRA)	D'Bastiani et al. (2020)
<i>Bokermannohyla caramaschii</i> (Napoli, 2005)	Undetermined	Undetermined	1/1	Santa Teresa, Espírito Santo (BRA)	Lemos et al. (2019)
<i>Bokermannohyla circumdata</i> (Cope, 1871)	Sarcophagidae	<i>Lepidodexia (Notochaeta) fumipennis</i>	22/1	Parque Estadual Pico do Marumbi, Paraná (BRA)	D'Bastiani et al. (2020)
	Sarcophagidae	<i>Peckia (Sarcodexia) lambens</i>	22/1	Parque Estadual Pico do Marumbi, Paraná (BRA)	D'Bastiani et al. (2020)
	Sarcophagidae	Undetermined	22/1	Parque Estadual Pico do Marumbi, Paraná (BRA)	D'Bastiani et al. (2020)
<i>Bokermannohyla hylax</i>	Undetermined	Undetermined	1/1	São José dos Pinhais, Paraná (BRA)	Present study
	Undetermined	Undetermined	1/1	São Luís do Paraitinga, São Paulo (BRA)	Lemos et al. (2019)
	Undetermined	Undetermined	1/1	Parque Natural Municipal Nascentes de Paranapiacaba, Santo André, São Paulo (BRA)	Present study

Table 3 (continued)

Host family and species	Myiasis-causing fly		Infested hosts	Location (country)	References
	Family	Species			
<i>Bokermannohyla luctuosa</i>	Undetermined	Undetermined	1/1	Tunas do Sul, Paraná (BRA)	Lenos et al. (2019)
	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Parque Pico das Cabras, Campinas and Morungaba, São Paulo (BRA)	Present study
	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Parque Pico das Cabras, Campinas and Morungaba, São Paulo (BRA)	Present study
<i>Calliniedusa tomopterna</i>	Undetermined	Undetermined	1/1	Reserva Florestal Adolpho Ducke, Manaus, Amazonas (BRA)	Present study
<i>Dendropsophus leali</i> (Bokermann, 1964)	Undetermined	Undetermined	1/1	Los Amigos Biological Station, Madre de Díos (PER)	von May et al. (2019)
<i>Dendropsophus schubarti</i> (Bokermann, 1963)	Sarcophagidae	<i>Lepidodexia</i> sp.	1/1	Cocha Cashu Biological Station (PER)	Junes et al. (2019)
<i>Dryaderces inframaculata</i> (Boulenger, 1882)	Sarcophagidae	Undetermined	1/1	Paranaíta, Mato Grosso (BRA)	Pinto et al. (2017)
<i>Osteocephalus</i> cf. <i>leprieurii</i> (Duméril & Bibron, 1841)	Undetermined	Undetermined	1/1	Los Amigos Biological Station, Madre de Díos (PER)	von May et al. (2019)
<i>Rheohyla miotympanum</i> (Cope, 1863)	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	2/2	Cascatas de Texolo, Veracruz (MEX)	Vázquez-Corzas et al. (2018)
	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Reserva Ecológica Santa Gertrudis, Veracruz (MEX)	Vázquez-Corzas et al. (2018)
<i>Scinax fuscovarius</i> (Lutz, 1925)	Calliphoridae	Undetermined	1/1	Salto de Pirapora, São Paulo (BRA)	Paredero et al. (2017)
	Sarcophagidae	Undetermined	1/1	Sabará, Minas Gerais (BRA)	de Souza-Pinto et al. (2015)
<i>Scinax x-signatus</i>	Undetermined	Undetermined	1/1	Águas de Santa Bárbara, São Paulo (BRA)	Present study
<i>Scinax</i> sp. (gr. <i>ruber</i>)	Undetermined	Undetermined	1/1	Fazenda São Nicolau, Cotriguaçu, Mato Grosso (BRA)	Present study
	Sarcophagidae	Undetermined	1/1	Fazenda Experimental da Universidade Federal do Amazonas, Manaus, Amazonas (BRA)	Present study
<i>Scinax</i> sp.	Sarcophagidae	Undetermined	1/1*	Sabará, Minas Gerais (BRA)	de Souza-Pinto et al. (2015)
	Sarcophagidae	Undetermined	3/1	Área de Proteção Ambiental Guaraqueçaba, Paraná (BRA)	D'Bastiani et al. (2020)
<i>Smilisca sordida</i>	Undetermined	Undetermined	1/1	Santa Rosa, Puriscal, San José (CRI)	Present study
<i>Trachycephalus typhonius</i>	Sarcophagidae	Undetermined	1/1	Ladário, Mato Grosso do Sul (BRA)	Silva et al. (2019)
Leptodactylidae					
<i>Physalaemus albonotatus</i> (Steindachner, 1864)	Sarcophagidae	<i>Lepidodexia (Notochaeta) adelina</i> Mulieri, Schaefer, Duré and González, 2018	1/1	Corrientes, Corrientes (ARG)	Mulieri et al. (2018)
<i>Physalaemus cuvieri</i>	Sarcophagidae	Undetermined	1/1	Pinheiros, Espírito Santo (BRA)	Martins et al. (2022)
	Undetermined	Undetermined	1/1	São José dos Pinhais, Paraná (BRA)	Present study

Table 3 (continued)

Host family and species	Myiasis-causing fly		Infested hosts Ne/Ni (P%)	Location (country)	References
	Family	Species			
<i>Physalaemus lateristriga</i> (Steindachner, 1864)	Undetermined	Undetermined	1/1	São José dos Pinhais, Paraná (BRA)	Present study
<i>Adenomera andreae</i>	Undetermined	Undetermined	1/1	Porto Trombetas, Oriximiná, Pará (BRA)	Present study
<i>Adenomera guarani</i> Zaracho, Lavilla, Carvalho, Motte & Basso, 2023	Sarcophagidae	<i>Lepidodexia (Notochaeta) adelina</i>	1/1	Corrientes, Corrientes (ARG)	Mulieri et al. (2018)
<i>Adenomera</i> sp.**	Sarcophagidae	Undetermined	8/1	Parque Estadual Pico do Marumbi, Paraná (BRA)	D'Bastiani et al. (2020)
<i>Adenomera</i> sp.1	Undetermined	Undetermined	1/1	Araguaína, Tocantins (BRA)	Present study
<i>Adenomera</i> sp.2	Undetermined	Undetermined	1/1	São José dos Pinhais, Paraná (BRA)	Present study
<i>Leptodactylus elenae</i> Heyer, 1978	Sarcophagidae	<i>Lepidodexia (Notochaeta) adelina</i>	1/1	Corrientes, Corrientes (ARG)	Mulieri et al. (2018)
<i>Leptodactylus fuscus</i>	Phoridae	<i>Megaselia scalaris</i>	122/2	Pantanal wetlands, Nhecolândia, Mato Grosso do Sul (BRA)	Alcantara et al. (2015)
	Sarcophagidae	<i>Oxysarcodexia carvalhoi</i> Lopes, 1946	122/3	Pantanal wetlands, Nhecolândia, Mato Grosso do Sul (BRA)	Alcantara et al. (2015)
<i>Leptodactylus luctator</i> (Hudson, 1892)	Undetermined	Undetermined	1/1	Botucatu, São Paulo (BRA)	Paredero et al. (2017)
<i>Leptodactylus rhodomystax</i>	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Marianópolis, Tocantins (BRA)	Present study
<i>Leptodactylus sertanejo</i>	Sarcophagidae	Undetermined	1/1	Vitória das Missões, Rio Grande do Sul (BRA)	Müller et al. (2015)
	Undetermined	Undetermined	1/1	Fazenda São Nicolau, Cotriguaçu, Mato Grosso (BRA)	Present study
	Undetermined	Undetermined	43/1 (2.3)	Águas de Santa Bárbara, São Paulo (BRA)	Present study
Microhylidae					
<i>Elachistocleis surinamensis</i>	Sarcophagidae	<i>Lepidodexia (Notochaeta)</i> sp.	1/1	Parque Nacional do Viúra, Caracará, Roraima (BRA)	Present study
Odontophrynidae					
<i>Proceratophrys boiei</i> (Wied-Neuwied, 1824)	Sarcophagidae	Undetermined	15/1	Área de Proteção Ambiental Guaraqueçaba, Paraná (BRA)	D'Bastiani et al. (2020)
<i>Proceratophrys</i> sp.	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Linhares, Espírito Santo (BRA)	Lopes (1981)
Ranidae					
<i>Aquarana castesbeiana</i>	Sarcophagidae	<i>Lepidodexia (Notochaeta)</i> sp.	8/8	Jundiá, São Paulo (BRA)	Souza Junior et al. (1989)
	Sarcophagidae	<i>Lepidodexia (Notochaeta)</i> sp.	2/2	Limeira, São Paulo (BRA)	Souza Junior et al. (1989)
	Undetermined	Undetermined	1/1	Jaraguá do Sul, Santa Catarina (BRA)	Present study
<i>Lithobates berlandieri</i> (Baird, 1859)	Sarcophagidae	<i>Lepidodexia (Notochaeta) bufonivora</i>	1/1	Francisco Xavier Clavijero Park, Xalapa, Veracruz (MEX)	Vázquez-Corzas et al. (2018)

Table 3 (continued)

Host family and species	Myiasis-causing fly		Infested hosts	Location (country)	References
	Family	Species			
Strabomantidae					
<i>Pristimantis achatinus</i> (Boulenger, 1898)	Sarcophagidae	Undetermined	1/1	Manizales, Caldas (COL)	Escobar-Vargas et al. (2016)
<i>Pristimantis thecopternus</i> (Lynch, 1975)	Undetermined	Undetermined	1/1	Salento, Quindío (COL)	Gómez-Hoyos et al. (2012)
Ne – number of examined individual hosts, Ni – number of infested individual hosts. Countries: ARG – Argentina, BRA – Brazil, COL – Colombia, CRI – Costa Rica, GUY – Guyana, MEX – Mexico, NIC – Nicaragua, PAN – Panama, PER – Peru, TTO – Trinidad and Tobago, VEN – Venezuela. NP – Not provided					
*Individual reported as <i>Scinax</i> gr. <i>ruber</i> by de Souza-Pinto et al. (2015), but based on the recent study on phylogenetic relationships of Scinaxini (Anura: Hylidae: Hylinae) in the Neotropics of Araújo-Vieira et al. (2023), we refer to individual as <i>Scinax</i> sp					
***Species identified as <i>Adenomera marmorata</i> Steindachner, 1867, but according to recent delimitation of Cassini et al. (2020), the species does not occur in the state of Paraná					

species) of the Neotropical amphibians (Rossa-Feres et al. 2017; Vancine et al. 2018). In this ecoregion, coastal and inland areas in southeastern Brazil have been inventoried since the 1980s (Rossa-Feres et al. 2017), thereby contributing to the highest concentration of cases of anuran myiasis in this region. Similarly, the Amazon rainforest is home to ~ 11% (947 species) of the amphibian species currently described worldwide (Penhacek et al. 2024). In this ecoregion, a greater research effort has been carried out in Peru and Brazil, resulting in the highest richness of amphibians among Amazonian countries (Penhacek et al. 2024), which contributes to the concentration of cases of anuran myiasis in the Amazon. The high number of records concentrated in the Atlantic Forest ecoregion in Brazil and in the Amazon rainforest in Peru and northern Brazil indicate that considerable knowledge gaps still need to be filled with information on myiasis-causing flies in other Neotropical regions.

During the literature search, we found studies reporting anuran species already known to host fly larvae that cause myiasis (Silva et al. 2019; D’Bastiani et al. 2020). After reviewing 14 studies not cited in previous reviews, we identified 15 species as additional records. These reviews listed 39 Neotropical anuran species affected by myiasis. Our 21 new hosts and the 15 additional hosts increase the number of anuran species known to be hosts of myiasis-causing flies to 75, corresponding to 2% of the 3,433 anuran species known in the Neotropical region (IUCN 2024).

On the other hand, the new interactions involving *Lepidodexia* (*Notochaeta*) *bufonivora* and *Lepidodexia* (*Notochaeta*) sp. and the high number of reports without identification show that the richness of myiasis-causing fly species remains underestimated, since unidentified fly taxa may represent unknown species (D’Bastiani et al. 2020). In addition, Sarcophagidae flies are primarily responsible for causing myiasis in Neotropical anurans, as described in most reports in which the larvae and adult flies were identified. Therefore, we reinforce the importance of the collaboration between herpetologists, entomologists and parasitologists to improve knowledge regarding the taxonomy and biology of these myiasis-causing flies and, consequently the interactions, thereby contributing to the reduction of Linnean and Eltonian shortfalls (Hortal et al. 2015).

Adults of different anuran families, such as those indicated herein as hosts of myiasis-causing flies, exhibit a wide variation in habitat use (Wells 2007). For example, hylids are more associated with arboreal habitats, while bufonids and leptodactylids have a close association with terrestrial habitats (Vasconcelos and Rossa-Feres 2008; Oda et al. 2016). While reviewing cases of myiasis in anurans that have been documented around the world, Silva et al. (2019) found that anurans belonging to the families Bufonidae and Miobatrachidae (terrestrial) were more frequently affected by myiasis than species of the family Hylidae (arboreal).

However, we found that Hylidae and Leptodactylidae are equally affected by myiasis in the Neotropical region. This predominance of anuran myiasis in Hylidae and Leptodactylidae may not only be related to habitat, but also to the availability of potential hosts. Studies have shown that arboreal and terrestrial habits, such as those exhibited by most hylids and leptodactylids respectively, may favor the occurrence of myiasis due to greater exposure to myiasis-causing flies searching for potential hosts (Hagman et al. 2005; Silva et al. 2019). In this context, we can assume that the high number of records of myiasis for Hylidae and Leptodactylidae, the most species-rich families in the Neotropics (Frost 2025), may also be explained by the greater availability of these anuran groups as potential hosts because of their ubiquity and abundance. In contrast, we recorded for the first time the occurrence of unidentified fly larvae of the family Sarcophagidae infesting tadpoles of *Rhinella marina* (Fig. 3a), which is an unexpected and intriguing record for the aquatic larval stage. Further studies are needed, however, to determine how flies deposit larvae on tadpoles.

A low prevalence of myiasis was observed in most reports, since they describe the finding of one or a few host individuals infested with fly larvae across several samples (e.g., Eizemberg et al. 2008; de Souza-Pinto et al. 2015; Lopez 2019; von May et al. 2019). In some cases, the prevalence may be slightly higher, as observed by Hagman et al. (2005) in *Ameerega trivittata* (Spix, 1824) in the Río Chumilla region, Peru. This low overall prevalence is probably related to the fortuitous nature of these observations (Mulieri et al. 2018). Furthermore, cases of myiasis are difficult to record and quantify in the field, since anuran hosts can die quickly due to the intense feeding behavior of the larvae on the host's body (e.g., Oliveira et al. 2012; de Souza-Pinto et al. 2015; López et al. 2016; Salazar-Saavedra et al. 2017).

The intensity of larval infestation is a determining factor for the survival of the anuran hosts (D'Bastiani et al. 2020). In some situations, it seems that the survival instinct causes infested anurans to exhibit reactive behaviors to the larval infestation. For example, terrestrial anurans (frogs and toads) have been recorded entering bodies of water (Roberts 1998; Blazuk 2011), which could be a reaction to pain or irritation, and even an attempt to drown the fly larvae. Here, in the case of *Bokermannohyla luctuosa*, one of the specimens presented expressive defensive behavior, the animal makes repetitive movements, opposite to the direction of the head, with the right hand over the lesion (Fig. 4a and 4b), perhaps in repetitive attempts to dislodge the fly larvae. The behavior of trying to remove larvae by repeatedly moving the hands over the wound seems to be more associated with arboreal species, as reported for *Bokermannohyla* and other hylids (Lemos et al. 2019; present study). Similar behavior was observed in *Hyla arborea* (Linnaeus, 1758), which uses its hands to remove eggs and larvae of *Lucilia bufonivora*

Moniez, 1876 (Meisterhans and Heusser 1970). However, to date, there are no systematic studies focused on specific (stereotyped) behaviors or complex behavioral responses exhibited by anuran hosts to remove fly larvae that cause myiasis.

A review study on the relationship between climate change and parasitic diseases of livestock predicts that the differential effects of global warming on mortality, development and transmission of ectoparasitic arthropods will vary widely among species (Morgan and Wall 2009). For myiasis-causing flies, such as the cosmopolitan blowfly *Lucilia sericata* (Meigen, 1826), Morgan and Wall (2009) suggest that warmer winters will favor their year-round development but will likely increase mortality of soil-dwelling larvae and pupae by increasing the activity of pathogens or causing a more rapid depletion of the larval metabolic reserves required for pupation (Pitts and Wall 2005). In this context, we raise the following question: Could climate change favor the development of myiasis-causing flies in the Neotropics? This could pose a new threat to anurans by increasing the prevalence and intensity of this parasitic phenomenon in a region that is home to the richest amphibian fauna in the world (Frost 2025; IUCN 2024), especially for endemic and threatened species. This perspective includes the consideration of a possible new threat to anurans. Therefore, we encourage further experimental and field studies that focus on the effects of climate change on the population dynamics and distribution of myiasis-causing flies in order to determine their impacts on anuran hosts in the Neotropics.

Conclusion

Our study reported 34 new cases of myiasis involving 31 species of anurans, in two countries of the Neotropical region. In addition, new associations between flies and hosts were observed involving the family Sarcophagidae, with two cases of the species *Lucilia bufonivora* and *Lucilia* sp., expanding the spectrum of Neotropical anuran species documented as hosts of fly larvae. This shows that a significant knowledge gap exists in the ecology of many Neotropical anuran species regarding the importance of parasitic diseases on population dynamics. Interactions between anurans and myiasis-causing flies may be more common than what has previously been reported in the literature, given the usual fortuitous nature of most observations. During our review, we also noticed that there is a large knowledge gap regarding myiasis in amphibians worldwide.

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Author's contribution FCS designed the research, collected data, and co-wrote the manuscript; VMG collected data, provided information and took photographs; APN collected data, participated in the literature review and co-wrote the manuscript; CSA collected data and co-wrote the manuscript; ALFS collected data and took photographs; RL collected data and took photographs; ESC collected data and took photographs; CAMP performed fly identification and co-wrote the manuscript; MS collected data and revised the manuscript; SPD collected data, provided information and took photographs; CB co-wrote and revised the manuscript; DJR collected data, co-wrote and revised the manuscript; VG collected data, co-wrote and revised the manuscript; LOD collected data and revised the manuscript; MM collected data, took photographs and revised the manuscript; CF collected data and photographs; RWA collected data, took photographs and revised the manuscript; CRR collected data; RGT collected data and revised the manuscript; PABAN collected data, performed fly identification, and took photographs; CA collected data; AGT collected data; MG collected data and co-wrote and revised the manuscript; AA collected data, co-wrote and revised the manuscript; BEN collected data; WVS collected data and took photographs; RCBP collected data and took photographs; MW collected data, co-wrote and revised the manuscript; KMC co-wrote and revised the manuscript; MMMS performed fly identification, took photographs, and revised the manuscript; FSCF performed fly identification and took photographs; ILK collected data and co-wrote the manuscript; JCOM collected data and co-wrote the manuscript; MM† designed the research and collected data; FHO designed the research, participated in the literature review, created the figures, and co-wrote the manuscript. All authors read and approved the final version of the manuscript.

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Data availability All the data supporting the findings of this study are available in the paper.

Declarations

Ethical approval Not Applicable.

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