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Review Article

A review on the occurrence of *Cochliomyia hominivorax* (Diptera: Calliphoridae) in Brazil

Revisão da ocorrência de *Cochliomyia hominivorax* (Diptera: Calliphoridae) no Brasil

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Abstract

Cochliomyia hominivorax (Coquerel, 1858), the New World screwworm, causes primary myiasis in wild and domestic animals in tropical and subtropical regions of Brazil. Although this species is considered to occur throughout the country, organized information about its recorded distribution has not been available until now. This article aimed to provide a comprehensive review of the historical and current data published on both immature (myiasis) and adult stages of *C. hominivorax* in Brazil. A total of 174 articles were found; of these, 141 articles reported myiasis cases in cattle (146 records), humans (68 records), and other mammalian hosts (40 records), and captures of adult flies were reported in 33 articles. *C. hominivorax* is widespread in Brazil, having been recorded in 208 municipalities in all major biomes of the country.

Keywords: Screwworm, primary miyasis, epidemiology, *Cochliomyia hominivorax*.

Resumo

Cochliomyia hominivorax (Coquerel, 1858), a mosca-da-bicheira, causa miíase primária em animais silvestres e domésticos em regiões tropicais e subtropicais do Brasil. Embora esta espécie seja considerada de ocorrência em todo o país, informações organizadas sobre sua distribuição com base em registros não estavam disponíveis até o momento. Este artigo teve como objetivo fornecer uma revisão abrangente dos dados históricos e atuais publicados sobre o registro de estágios imaturos (miíase) e adultos de *C. hominivorax*, no Brasil. De 174 artigos encontrados, 141 relataram casos de miíase em bovinos (146 relatos), humanos (68 relatos) e outros mamíferos hospedeiros (40 relatos) e capturas de adultos de *C. hominivorax* foram registradas em 33 artigos. *C. hominivorax* encontra-se amplamente distribuída no Brasil, tendo sido registrada em 208 municípios brasileiros em todos os principais biomas do país.

Palavras-chave: Mosca-da-bicheira, miíase primária, epidemiologia, *Cochliomyia hominivorax*.

Introduction

The New World screwworm (NWS) fly, *Cochliomyia hominivorax* (Coquerel, 1858) (Diptera: Calliphoridae), is a major cause of primary myiasis in animals in tropical and subtropical regions of the Americas (WYSS, 2000). The original distribution of this species extended from the southern United States to central Argentina, including the Caribbean (HALL & WALL, 1995). Beginning in 1957, a program based on the sterile insect technique eradicated *C. hominivorax* from North and Central America (WYSS, 2000). Currently, a biosecurity facility for screwworm mass rearing, sterilization, and dispersal is maintained in Panama for preventing reintroduction from Colombia (CONCHA et al., 2016). The current distribution of this species comprises the Caribbean and South America, except Chile (FRESIA et al., 2011).

Myiasis is a parasitic infestation of live vertebrate animals by dipterous larvae (ACHA & SZYFRES, 2003). Although

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several dipteran species may cause myiasis (ZUMPT, 1965; HALL & WALL, 1995; GUIMARÃES & PAPAVERO, 1999), *C. hominivorax* is the main species associated with primary myiasis in Brazil (ZUMPT, 1965).

In Brazil, cattle myiasis is more prevalent in newborn calves and is eventually associated with tick infestations (YARZON, 2005; BARROS et al., 2010a; RECK et al., 2014). Aggravated by favorable environments, infrastructure problems and management difficulties, myiasis stands out among the main causes of calf mortality in some Brazilian regions (BARROS et al., 2010b; GRISI et al., 2014).

Although *C. hominivorax* is widely spread throughout the country, information on the distribution and epidemiology of this species in Brazil is scattered, and little information is available about its geographic distribution as well as the prevalence of its myiasis in different host species. A comprehensive study on screwworm distribution in Brazil was performed some decades ago by Horn & Antônio (1983) when a questionnaire was distributed all over the country by the Serviço Brasileiro de Defesa Sanitária Animal; with a return rate of approximately 75%, the occurrence of myiasis was recorded in 96.2% of the municipalities from all Brazilian states. In that survey, the highest myiasis prevalence was observed in the Northeast states; in 495 municipalities, screwworm myiasis was the most prevalent cattle ectoparasitosis (HORN & ANTÔNIO, 1983).

In this sense, the present article is a comprehensive compendium of the historical and current data published about the occurrence of *C. hominivorax* and its myiasis in Brazil. Aspects related to the etiology, distribution, and host occurrence of cutaneous myiasis, mainly due to *C. hominivorax*, are presented to update the overview of this important parasite.

Review procedures

The present review comprised a comprehensive search of technical and scientific publications using searching tools and databases, such as PubMed, Scielo and Google Scholar, available on the internet. Searching was conducted until December 2017 using several combinations of screwworm-related terms (Calliphoridae, *Cochliomyia*, myiasis, screwworm) as well as related hosts (cattle, horse, dog, sheep, human) and "Brazil". Articles about adult trapping without the species (*C. hominivorax*) identification were not considered.

This review included not only new and old information available on the internet but also published articles not available online. Information regarding the occurrence of myiasis in wildlife is very scarce in the Brazilian literature; thus, additional information was provided by some field professionals working in that area.

This paper was mostly based on myiasis records from both case reports and field studies, depending on the host species. Complementary information from adult records, mostly from trapping studies, was also included. Eventually, the number of records was greater than the number of articles since some articles had multiple records.

General results

The present review covered 227 articles published over the last 142 years (1875 - 2017) reporting myiasis (by different species) and screwworm adult trapping in Brazil. Of these, 174 articles recorded *C. hominivorax*, with 81.1% (141 articles) reports on myiasis and 18.9% (33 articles) records of adult trapping.

From 1875 to 1999, only 24 articles (14.2%) reported *C. hominivorax* in Brazil (Figure 1). The number of such articles increased considerably, with 49 (29.0%) reports from 2000 to 2008, and peaked from 2009 to 2017, with 96 (56.8%) published articles (Figure 1). It is worth mentioning that until 1999, only a few publications had reported the occurrence of both human myiasis (n= 2) and adult trapping (n= 3); however, such reports increased considerably to 34 and 25 articles, respectively, from 2009 to 2017. In addition to those 168 articles, six other articles with no identified hosts were excluded from the analysis.

The occurrence of *C. hominivorax* has been recorded by technical and/or scientific publications in 208 municipalities from 26 states of Brazil. No published records of *C. hominivorax* were found for the state of Alagoas (Northeast region); however, myiasis by *C. hominivorax* and/or adult catches has been recorded in neighboring states. Anecdotal information from field veterinarians confirms its distribution in all Brazilian states. Without confirming species identification, Horn & Antônio (1983) had previously reported the occurrence of cattle myiasis in all states of the country.

Most published records (41.8%) of both screwworm myiasis (on all hosts) and adult catches were from the Southeast region of the country (Table 1); however, this finding most likely resulted from a much greater number of studies carried out in that region during the years rather than a higher abundance of this fly in the region. Indeed, the number of published reports ultimately reflects the number of studies conducted in each particular region and does not necessarily represent (or should be interpreted as an indicator of) screwworm abundance or importance.

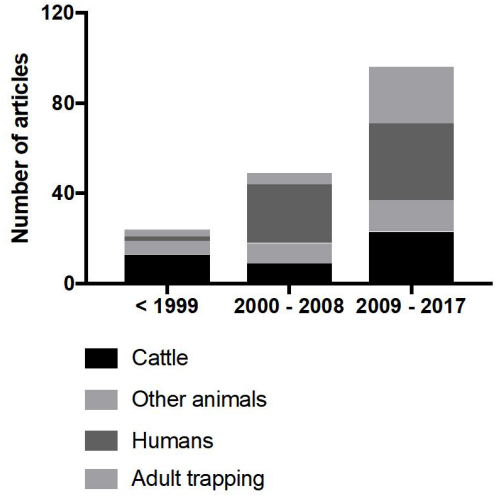

Figure 1. Temporal distribution of scientific publications (n= 168) recording *Cochliomyia hominivorax* immatures (myiasis) and adults' in Brazil from 1875 to 2017.

Cattle Myiasis

The specific occurrence of cattle myiasis was recorded in 127 municipalities distributed throughout all five regions of the country (Figure 2A, Table 2). *Cochliomyia hominivorax* was the most important species associated with cattle myiasis in Brazil and was responsible for all cases where the etiologic agent was identified (Table 3). The distribution of cattle myiasis in Brazil is certainly broader than it is presented here (Table 2 and Figure 2A), as suggested by Horn & Antônio (1983). However, a more complete distribution of this pest depends on further studies, mainly in regions where information is scarce or simply does not exist. The absence of species confirmation, as observed in several reports, also limits epidemiological studies.

The highest number of records of myiasis in cattle (87.6%) was recorded in the Southeast (34.2%), Midwest (30.8%) and South (22.6%) regions (Table 1). This distribution is highly influenced by two major factors: 1) a greater number of scientific articles in the

Table 1. Frequency distribution (%) of *Cochliomyia hominivorax* myiasis and adult records from articles published from 1875 to 2017 (n = 174) in Brazil.

Region	Myiasis records*			Trapping records	Total
	Humans	Cattle	Other hosts		
North	5.9 (4)	6.8 (10)	2.5 (1)	10.5 (4)	**6.5 (19)**
Northeast	13.2 (9)	5.5 (8)	27.5 (11)	21.1 (8)	**12.3 (36)**
Midwest	1.5 (1)	30.8 (45)	15.0 (6)	26.3 (10)	**21.2 (62)**
Southeast	63.2 (43)	34.2 (50)	45.0 (18)	28.9 (11)	**41.8 (122)**
South	16.2 (11)	22.6 (33)	10.0 (4)	13.2 (5)	**18.2 (53)**
Total of Records	**68**	**146**	**40**	**38**	**292**

*Records without host (n = 32) or state (n = 1) identification were not considered in the present analysis. The frequency is followed by number of records in this table.

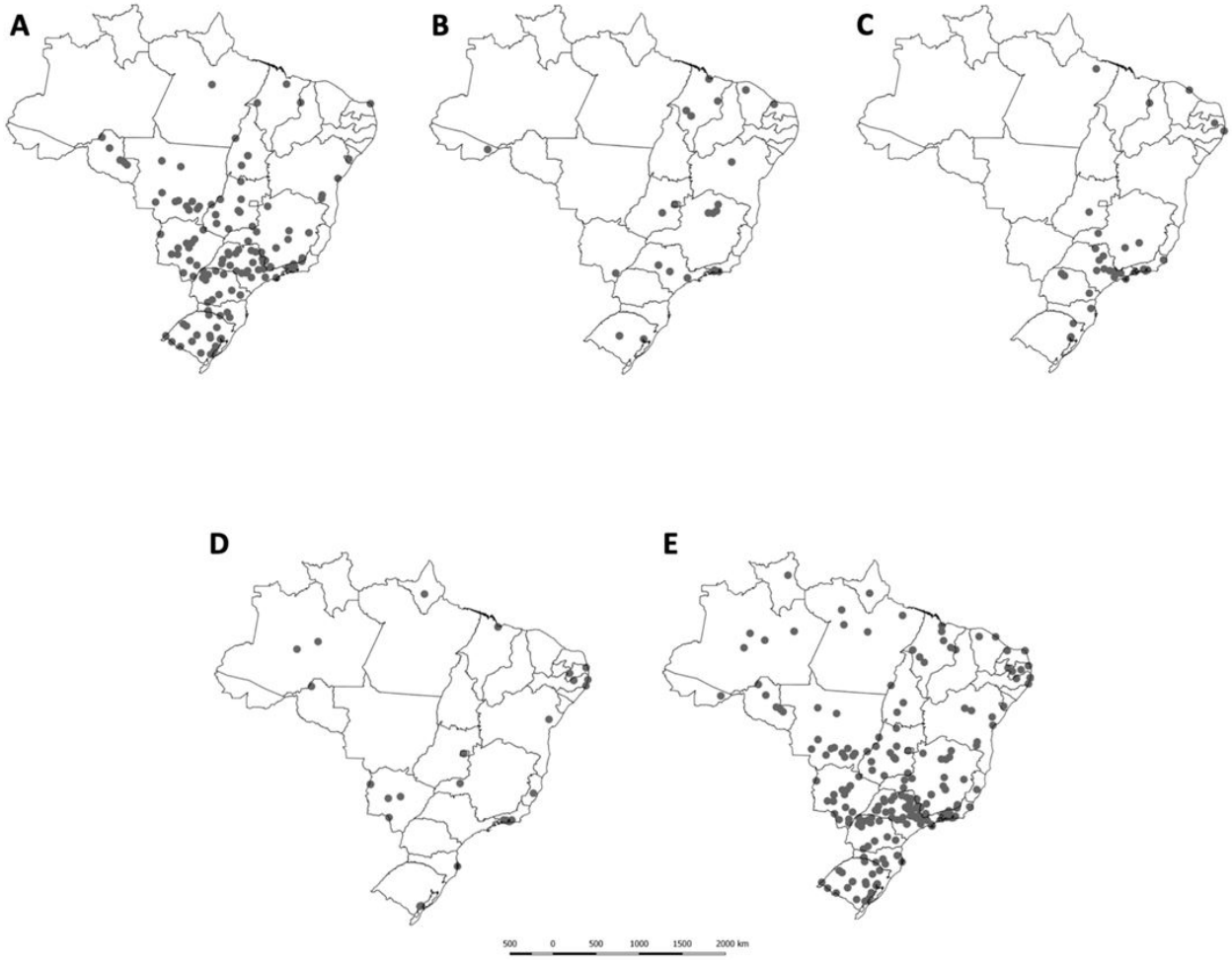

Figure 2. Distribution of *Cochliomyia hominivorax* records in Brazil: cattle myiasis (A); pets, other livestock and wildlife myiasis (B); human myiasis (C); adult trapping (D); and overall species distribution (E). Records without host were considered to overall species distribution map.

Table 2. Geographic occurrence of *Cochliomyia hominivorax* according to published records of myiasis occurrence and adult catches in Brazil.

State	Municipalities	Reference
AC	Rio Branco	Fresia et al., 2014; Mastrangelo et al., 2014; Reis et al., 2016
AM	Coari[1], Manaus, Porto Urucu[1], Tefé	Lessinger & Azeredo-Espin, 2000; Litjens et al., 2001; Azeredo-Espin & Lessinger, 2006; Esposito et al., 2010; Sousa et al., 2010; Fresia et al., 2014; Mastrangelo et al., 2014
AP	Serra do Navio[1]	Couri et al., 2000
BA	Barra do Choça, Feira de Santana[1], Irecê, Itambé, Jaguaripe, Morro do Chapéu	Azeredo-Espin, 1987; Caproni et al., 1998; Junqueira et al., 2002; Azeredo-Espin & Lessinger, 2006; Almeida et al., 2008; Fresia, 2011; Bergamo et al., 2015; Santos & Andena, 2017
CE	Fortaleza, Sobral	Costa & Vieira, 1984; Jorge et al., 2016
DF	Brasília[2]	Cansi et al., 2011; Cansi & Bonorino, 2011; Cansi & Demo, 2011; Harterreiten-Souza & Pujol-Luz, 2012; Name et al., 2012; Kosmann, 2013
ES	Santa Teresa[1]	Barbosa et al., 2014
GO	Caiapônia, Catalão, Goianésia, Goiânia, Goianira, Itaberaí, Jataí, Jussara, Porangatu, Quirinópolis, Rio Verde	Lustosa et al., 1983; Azeredo-Espin, 1987; Caproni et al., 1998; Garcia-Zapata et al., 2005; Fernandes et al., 2009; Lyra et al., 2009, 2010; Carvalho et al., 2009; Carvalho et al., 2010; Fresia et al., 2011; 2013; 2014; Silva et al., 2011; Cardoso et al., 2014, 2016; Lopes et al., 2014; Bergamo et al., 2015; Teixeira et al., 2016
MA	Caxias, Coroatá, Formosa da Serra Negra, Grajaú, Santa Rita, São Francisco do Brejão, São Luís, Sítio Novo	Caproni et al., 1998; Brito et al., 2005; Reis et al., 2008; Figueiredo et al., 2010; Fresia et al., 2014; Mastrangelo et al., 2014; Pereira de Sousa et al., 2015, 2016
MG	Além Paraíba, Alfenas, Belo Horizonte, Capim Branco, Coração de Jesus, Estiva, Formiga, Francisco Sá, Governador Valadares, Janaúba, Leopoldina, Monte Carmelo, Montes Claro, Poços de Caldas, Presidente Juscelino, Santa Vitória, São Sebastião do Paraíso, Uberaba, Uberlândia[2], União de Minas, Veríssimo	Azeredo-Espin, 1987; Caproni et al., 1998; Lessinger & Azeredo-Espin, 2000; Litjens et al., 2001; Duarte et al., 2012; Junqueira et al., 2002; Gomez et al., 2003; Lima et al., 2004; Abdo et al., 2006; Oliveira et al., 2008; Silva, 2008; Amos, 2009; Lyra et al., 2009, 2010; Fresia et al., 2011; 2013; 2014; Silva et al., 2011; Ribeiro et al., 2012b; Lopes et al., 2013; Teixeira et al., 2013; Bergamo et al., 2015; Silva et al., 2015; Faria et al., 2018
MS	Amambaí, Aquidauana[2], Bandeirante, Bonito, Camapuã, Campo Grande[2], Corumbá[2], Costa Rica, Itaquiraí, Ivinhema, Jardim, Naviraí, Nioaque, Ponta Porã[1], Rio Brilhante, Rochedo, Três Lagoas	Bianchin et al., 1991, 1992; Caproni et al., 1998; Gomes et al., 1998; Koller et al., 2002, 2011; Oliveira et al., 2006; Pires, 2008; Lyra et al., 2009; Barros et al., 2010a,b; Corrêa et al., 2010; Xavier, 2010; Fresia et al., 2011; 2013; 2014; Taira et al., 2011; Luiz et al., 2012; Bergamo et al., 2015; Souza et al., 2016; Kosmann et al., 2017; Salinas & Lima, 2017
MT	Barra das Garças, Chapada dos Guimarães, Cocalinhos, Cuiabá, Guiratinga, Juara, Jucimeira, Primavera do Leste, Rondonópolis, São José dos Quatro Marcos, Sinop, Tangará da Serra, Tesouro	Rivera & Aycardi, 1985; Azeredo-Espin, 1987; Caproni et al., 1998; Fresia et al., 2011; 2013; 2014
PA	Alenquer, Altamira, Belém, Santa Maria das Barreiras, Santarém	Caproni et al., 1998; Seppanen et al., 2004; Saraiva et al., 2006; Gomes de Araújo et al., 2009; Lyra et al., 2009; Silva et al., 2011; Fresia et al., 2011; 2013; 2014; Ribeiro et al., 2012a; Mastrangelo et al., 2014
PB	Campina Grande, Patos, Rio Tinto[1], São José dos Cordeiros[1]	Fresia et al., 2013; Alves et al., 2014; Cavalcante et al., 2015; Holanda et al., 2015
PE	Brejo da Madre de Deus[1], Recife[2], Tamandaré[1]	Melo et al., 2003; Nascimento et al., 2005; Fresia, 2011; Laureano-Filho et al., 2011; Figueirêdo et al., 2015; Oliveira et al., 2016; Arruda et al., 2017

Municipalities with no numbers mean myiasis records; numbered sites mean *C. hominivorax* adult catches (1) and adult catches/myiasis records (2).

Table 2. Continued...

State	Municipalities	Reference
PI	Teresina	Caproni et al., 1998; Silva et al., 2005a, b; Lopes-Costa et al., 2008; Fresia et al., 2014; Mastrangelo et al., 2014
PR	Carambeí, Colombo, Guarapuava, Jataizinho, Jundiaí Sul, Loanda, Mangueirinha, Maria Helena, Maringá, Nossa Senhora das Graças, Nova Esperança, Pato Branco, Paraíso do Norte, Sarandi, Tuneiras Oeste	Caproni et al., 1998; Chicarelli et al., 2002; Gealh et al., 2009; Kotze et al., 2009; Lyra et al., 2009, 2010; Fresia et al., 2011; 2013; 2014; Silva et al., 2011; Costa et al., 2012; Bergamo et al., 2015
RJ	Andaraí, Angra dos Reis, Barra do Piraí; Barra Mansa, Belford Roxo, Campos dos Goytacazes, Duque de Caxias, Itaboraí[1], Itaguaí, Miguel Pereira, Niteroi[1], Nova Iguaçu[2], Rio das Flores, Rio de Janeiro[2], São Gonçalo, Seropédica[2], Tinguá[1]	Oliveira, 1980; D'Almeida, 1983; Muniz et al., 1995; Sanavria & Prata, 1996; Taylor et al., 1996; Caproni et al., 1998; Figueiredo et al., 2002, 2006; Passos et al., 2002; Cramer-Ribeiro et al., 2002a,b, 2003; Oliveira et al., 2006; D'Almeida & Fraga, 2007; Marquez et al., 2007; Mendes-de-Almeida et al., 2007; Deleito & Moya-Borja, 2008; Ferraz et al., 2008, 2010a,b; 2011; Rodrigues-Guimarães et al., 2008; Pires, 2008; Batista-da-Silva et al., 2009; Correia et al., 2010; Ferraz et al., 2010a, b; Souza CP et al., 2010a; Souza JR et al., 2010b; Batista-da-Silva et al., 2011a, b, c, 2012; Batista-da-Silva, 2015; Braga et al., 2011; Fresia, 2011; Gonçalves et al., 2011; Marotta et al., 2011; Marotta et al., 2011; Lucares et al., 2013; Oliveira-Costa et al., 2013; Valviesse et al., 2014; Azevedo et al., 2015; Gadelha et al., 2015; Rodrigues et al., 2017; Oliveira et al., 2018
RN	Mossoró, Touros	Bezerra et al., 2010; Fresia et al., 2011; 2013; 2014; Bergamo et al., 2015
RO	Ariquemes, Cacoal, P. Bueno, Porto Velho[2], Presidente Médici	Caproni et al., 1998; Serbino et al., 2010
RR	Boa Vista	Fresia et al., 2014; Mastrangelo et al., 2014
RS	Bossoroca, Camaquã, Canoas, Capão do Leão[2], Fagundes Varela, Guaíba, Pelotas, Pinheiro Machado, Pelotas[1], Porto Alegre, Quaraí, Rio Pardo, Santa Cruz do Sul, Santa Maria, Santana do Livramento, Santo Antônio das Missões, São Gabriel, São Lourenço do Sul, São Valentim, Uruguaiana, Vacaria	Souza, 1939; Azeredo-Espin, 1987; Ribeiro et al., 1993; Taylor et al., 1996; Ribeiro et al., 1997; Caproni et al., 1998; Junqueira et al., 2002; Vianna et al., 2004; Spagnol et al., 2006; Manfrim et al., 2007; Rossi-Schneider et al., 2007; Fighera, 2008.; Lyra et al., 2009, 2010; Barrientos Pontes et al., 2009; Souza et al., 2009; Carmo et al., 2011; Fresia et al., 2011; 2013; 2014; Silva et al., 2011; Martins et al., 2012; Schmidt et al., 2012; Azevedo & Krüger, 2013; Reck et al., 2014; Bergamo et al., 2015
SC	Blumenau, Celso Ramos, Chapecó, Curitibanos, Florianópolis[1]; Lages	Caproni et al., 1998; Martins-Junior et al., 2010; Paim, 2010; Bernaschina, 2016
SE	Riachão do Dantas	Caproni et al., 1998
SP	Adamantina, Águas da Prata, Amparo, Araçatuba, Arandu, Araraquara, Barretos, Batatais, Botucatu; Bragança Paulista, Campinas, Caraguatatuba, Cravinhos, Garça, Ilhabela, Ipiguá, Itapetininga, Itatinga, José Bonifácio, Martinópolis, Morro Agudo, Nova Odessa, Oscar Bressane, Paulínia, Piracicaba, Pirassununga, Poconé, Presidente Prudente, Ribeirão Preto, Santa Cruz do Rio Pardo, Santo Antônio do Aracanguá, São Carlos, São João da Boa Vista, São José do Rio Pardo, São José dos Campos, São Paulo, Valinhos	Vaz & Carvalho, 1938; Rocha & Vaz, 1950; Abdallah et al., 1970; Azeredo-Espin, 1987; Silva et al., 1991; Amarante et al., 1992; Vargas & Azeredo-Espin, 1995; Caproni et al., 1998; Rocha et al., 1999; Gennari et al., 2000; Lessinger et al., 2000; Litjens et al., 2001; Ribeiro et al., 2001; Junqueira et al., 2002; Martinez et al., 2003; Rodriguez et al., 2003; Shinohara et al., 2004; Tarso et al., 2004; Azeredo-Espin & Lessinger, 2006; Pasternak et al., 2007; Pena, 2007; Takahagi et al., 2007; Barbosa et al., 2008; Rossi et al., 2009; Lima-Júnior et al., 2010; Lyra et al., 2010; Loureiro et al., 2010; Ribeiro et al., 2010; Antunes et al., 2011; Fresia et al., 2011; 2013; 2014; Vale et al., 2011; Ribeiro et al., 2012a; Thyssen et al., 2012; Lopes et al., 2013, 2017; Sellera et al., 2014; Baptista, 2015; Novo-Neto et al., 2015; Giglioti et al., 2016; Ribeiro & Monnazzi, 2016; Calderon et al., 2017
TO	Araguaína, Gurupi, Porto Nacional	Rivera & Aycardi, 1985; Caproni et al., 1998

Municipalities with no numbers mean myiasis records; numbered sites mean *C. hominivorax* adult catches (1) and adult catches/myiasis records (2).

Table 3. Frequency of published records of myiasis by dipteran species and hosts in Brazil.[1]

Diptera species	Cattle (n = 150)	Humans (n = 108)[a]	Small ruminants (n = 30)	Others domestic animals (n = 28)	Wild mammals (n = 5)
Calliphoridae					
Cochliomyia hominivorax	97.3 (146)	63.9 (69)	56.7 (17)	64.3 (18)	80.0 (4)
Cochliomyia macellaria	-	2.8 (3)	-	-	-
Chrysomya albiceps	-	2.8 (3)	3.3 (1)	-	-
Chrysomya megacephala	-	1.8 (2)	-	-	-
Lucilia cuprina	-	2.8 (3)	-	-	-
Lucilia eximia[2]	-	-	-	14.3 (4)	20.0 (1)
Syrphidae					
Eristalis tenax	-	2.8 (3)	-	-	-
Ornidia obesa	-	0.9 (1)	-	-	-
Muscidae					
Musca domestica	-	0.9 (1)	-	3.6 (1)	-
Sarcophagidae	-	5.6 (6)[3]	-	-	-
Not identified	2.7 (4)	15.7 (17)	40.0 (12)	17.9 (5)	-

[a]Three articles recorded infestation by three distinct species. [1]Multiple records of myiases caused by the same species in the same municipality were considered just once. [2]*Phaenicia eximia* was considered a synom of *Lucilia eximia*. [3]Includes *Sarcophaga pyophila*, *Sarcophaga ruficornis, Sarcodexia lambens* and *Sarcophaga* sp.

area of agrarian sciences from researchers in the Southeast, South and Midwest, totaling 86% (1992-1994) and 79% (2007-2009) of Brazilian scientific production (SIDONE et al., 2016), and 2) a larger cattle herd in these regions, representing 66% and 78% of the national bovine population in 1980 and 2010, respectively (IBGE, 2018).

Forty-five articles provided 146 reports of cattle myiasis; of these, 20 were about molecular or biochemical aspects, 16 were tests of drug or plant extract efficacy, and the others were case reports (four articles), epidemiology (three articles), general survey of ectoparasites (one article) and control using the sterile insect technique (one article).

Myiasis on other animal hosts

Several domestic animals have been reported as hosts to dipteran larvae in Brazil (Table 3). Most records were from myiasis in dogs (n= 14), followed by cats (n= 8), horses (n= 2), and buffalo, donkey, rabbits and pigs (n= 1, each). In general, the clinical resolution of myiasis in domestic animals will depend on the location and extent of injury, intensity of infestation, speed of diagnosis and effective treatment, and the dipteran species involved (CORREIA et al., 2010).

Cochliomyia hominivorax was responsible for 64.3% of the myiasis reported in domesticated animals (other than bovines), which included dog, cat, goat, sheep, horse, donkey, buffalo and pig, in various regions of the country.

Myiasis in pets due to *C. hominivorax* has been reported in dogs and cats. Nine articles reported the occurrence of myiasis in dogs in the states of Rio Grande do Sul (SPAGNOL et al., 2006; FIGHERA, 2008; SOUZA et al., 2009), Rio de Janeiro (CRAMER-RIBEIRO et al., 2003; CORREIA et al., 2010), Federal District (CANSI & DEMO, 2011; NAME et al., 2012), São Paulo (PENA, 2007) and Goiás (LUSTOSA et al., 1983). Myiasis in cats has been reported only in Rio de Janeiro (MENDES-DE-ALMEIDA et al., 2007; SOUZA CP et al., 2010a; MAROTTA et al., 2011) and the Federal District (CANSI & DEMO, 2011). The occurrence of myiasis in pets is certainly underestimated in all states.

Brazil has more than eight million goats and thirteen million sheep, concentrated in the Northeast and South regions (IBGE, 2018). Thirty records of myiasis (by distinct species) in small ruminants, including 19 in sheep and 11 in goats (Table 3), from 11 states, were found in 13 articles. Approximately 56.6% of the records (n= 17) were from the Northeast region (Table 2), although most of this region is semiarid and has a smaller number of myiasis cases.

Most myiasis reports in small ruminants in Brazil were caused by *C. hominivorax* (n= 17 records); however, in 40% of the records, the species was not identified (Table 3). Small ruminants infested by myiasis could be mutilated because of the rapid development of myiasis, often in less than 24 hours. The articles recording myiasis by *C. hominivorax* in small ruminants were case reports (SCHMIDT et al., 2012; SELLERA et al., 2014; REIS et al., 2016), surveys of ectoparasites (COSTA & VIEIRA, 1984; BRITO et al., 2005; BEZERRA et al., 2010), epidemiology studies (AMARANTE et al., 1992; DUARTE et al., 2012) and ectoparasiticide efficacy trials (SANAVRIA & PRATA, 1996).

Although *C. hominivorax* was responsible for the majority (64.3%) of the myiasis reported in domesticated animals (other than bovines), *Lucilia eximia* (Wiedemann, 1981) has been found in 14.3% of cases (Table 3), including dogs, cats, and rabbits (MADEIRA et al., 1989; AZEREDO-ESPIN & MADEIRA, 1996; MORETTI & THYSSEN, 2006; CANSI & DEMO, 2011).

Relatively little information is available regarding the occurrence of myiasis in wild animals in Brazil. In nature, primary myiasis caused by *C. hominivorax* has been reported only in the maned wolf (*Chrysocyon brachyurus* Illiger, 1815) in Brasilia (CANSI et al., 2011) and opossum (*Didelphis marsupialis* Linnaeus, 1758) in Caxias, Maranhão state (REIS et al., 2008). In captive animals, myiasis by *C. hominivorax* has been recorded in the hippopotamus

(*Hippopotamus amphibious* Linnaeus, 1758) and the lesser grison (*Galictis cuja* Molina, 1782) in São Paulo and São Luís (ROSSI et al., 2009; FIGUEIREDO et al., 2010). Myiasis by other species has also been reported in a captive white-eared opossum (*Didelphis albiventris* Lund, 1840) from Brasilia caused by *L. eximia* (CANSI & BONORINO, 2011). Except for *D. albiventris*, all myiasis reported in wild mammals in Brazil was caused by *C. hominivorax*.

The scarcity of information on myiasis in wild mammals should not be considered as the absence of this problem in wildlife, but to the lack of specific studies as well as a better use of field opportunities during ecological studies.

Additional unpublished or anecdotal observations of myiasis in wildlife also included puma (*Puma concolor* Linnaeus, 1771) in 2013 from São Paulo and Minas Gerais (Fernanda C. Azevedo e Frederico G. Lemos, personal communication), red-footed tortoise (*Geochelone carbonaria* Spix, 1824) in 2011 from Uberaba, Minas Gerais state and maned wolf in the mountain region of Rio de Janeiro in. In all those cases, the actual species causing myiasis is unknown.

Although the parasitism of birds by *C. hominivorax* larvae is quite uncommon, such a situation has been found in a captive ostrich (*Struthio camelus* Linnaeus, 1758) in the semiarid region of the state of Bahia (ALMEIDA et al., 2008). Indeed, myiasis in small wild birds of several species is commonly caused by *Philornis* larvae (LUZ et al., 2008, 2010, 2011; FRANZ & COURI, 2008).

Myiasis due to the primary screwworm has not been reported in anurans and reptiles in Brazil. However, Sarcophagidae larvae have been found in tree frogs (*Hypsiboas beckeri* Caramaschi and Cruz, 2004 and *Aplastodiscus arildae* Cruz and Peixoto, 1987) (EIZEMBERG et al., 2008; MELLO-PATIU & LUNA-DIAS, 2010) and in the introduced American bullfrog (*Rana catesbeiana* Shaw, 1802) (SOUZA et al., 1989). The single record of myiasis in reptiles in Brazil was from the South American rattlesnake (*Crotalus durissus* Linnaeus, 1758) caused by Phoridae larvae (SILVA et al., 1999).

Human Myiasis

Zoonotic infestations by dipteran larvae are of great public health importance, and people with inadequate hygienic habits are the most likely to have cutaneous lesions and/or systemic diseases, thus becoming more susceptible to such infestations (MARTINEZ et al., 2003). Clinical manifestations of myiases depend on the dipteran species involved and the organ or tissue affected (PIERCE, 1981), and the prognosis is directly related to the duration and location of the injury and the health conditions of the patient (NASCIMENTO et al., 2005).

One of the first reports of myiasis in Brazil was by Brandão & Menezes (1875), who included more than 30 cases in humans, mainly in nasal cavities; unfortunately, the species was not identified. Since then, some cases of human mortality due to myiasis have been reported in Brazil (BLEYER, 1905; SOUZA, 1939; CARVALHO et al., 2008; HOLANDA et al., 2015).

Human myiasis has been recorded in 44 municipalities from 15 states in all regions of Brazil (Figure 2C, Table 1, Table 2). Most reports (59.7%) refer to the occurrence of myiasis in the head and neck; however, there are also several cases of genital myiasis. The vast majority (n= 51) of the articles about human myiasis caused by *C. hominivorax* are limited to simple case descriptions, and only a few articles show a therapeutic and/or epidemiological approach. Most records of human myiasis in Brazil are from the Southeast region (63.2%) (Table 1), particularly from Rio de Janeiro and São Paulo, which represent 29.4% and 26.4%, respectively, of all records of human myiasis from Brazil.

Although several dipteran species have been identified in human myiasis, *C. hominivorax* is by far the most important species, present in 63.9% of the cases. Other etiological agents of human myiasis included sarcophagids, found in 5.6% of the particles, as well as *Cochliomyia macellaria* (Fabricius, 1775), *Chrysomya albiceps* (Wiedemann, 1819), *Eristalis tenax* (Linnaeus, 1758) and *Lucilia cuprina* (Meigen, 1826) identified in 2.8% of the cases (Table 3).

Adult records

Although myiasis studies themselves have provided robust information on screwworm distribution in Brazil, the lack of such studies in some states leaves a gap in the occurrence of this species in those regions. Actually, the absence of specific information for a particular region does not necessarily imply that either livestock or myiasis are not important at the region; instead, it most probably reflects the absence of studies on this particular subject in that state.

Additional information obtained from screwworm adult captures contributed to providing a more complete distribution of *C. hominivorax* in the country (Figure 2D, Table 2). Adults of *C. hominivorax* have been caught in several sites, mainly by traps baited with carcasses (ALVES et al., 2014; FARIA et al., 2018), rotting viscera or other decaying material (KOLLER et al., 2002, 2011; SOUSA et al., 2010; GONÇALVES et al., 2011; GADELHA et al., 2015; PEREIRA DE SOUSA et al., 2015, 2016; OLIVEIRA et al., 2016). Although decaying baits are not the best attractant to a fly species causing primary myiasis, this relatively inexpensive and simple choice has provided useful information on the distribution of *C. hominivorax* in Brazil (Figure 2E). In fact, of the 33 articles recording catches of *C. hominivorax* adults, 31 were about general Calliphoridae ecology or epidemiology.

In general, of the 325 records with information on *C. hominivorax* distribution in Brazil, only 38 (11.7%) came from trapping studies. Although relatively little information was provided by such studies, *C. hominivorax* adults were caught in 14 states (Table 1), expanding their distribution to two more states and nine municipalities in which no information on myiasis was previously available.

Those situations reinforce that, despite the considerable number of studies on myiasis, the geographic distribution of the species in the country is not limited to the regions where such studies have been conducted.

Conclusions

Cochliomyia hominivorax is the most important species causing primary myiasis in livestock, pets and man in Brazil. Geographic distribution of the screwworm in Brazil based on historical and

recently published data confirms its distribution throughout the country. Although most records were from cattle studies, the occurrence of primary myiasis has been quite reported in pets as well as in humans, evidence of the social and economic importance of the screwworm in both human and animal health.

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