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INVENTORY OF MOSQUITOES (DIPTERA: CULICIDAE) IN CONSERVATION UNITS IN BRAZILIAN TROPICAL DRY FORESTS

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SUMMARY

In Brazil, most studies of the Culicidae family are concentrated in rainforest regions. As such, there is a lack of knowledge regarding the diversity of Culicidae in regions with different climatic and vegetational characteristics. The aim of this study was to compile an inventory of Culicidae in protected areas of the semi-arid region of the state of Minas Gerais, Brazil, in order to better understand the diversity of the family within this region. The study was conducted across four protected areas in the northern region of the state, in tropical dry forest (TDF) fragments. Sampling methods included Shannon trap and CDC light trap, as well as active collection. A total of 11,219 mosquito specimens were collected between August 2008 and July 2012, belonging to 11 genera and 45 species; 15 new records for the state of Minas Gerais were registered, as well as 26 new records for semi-arid regions within the state. The high number of new Culicidae records in this region demonstrates the importance of inventory studies for increasing the knowledge of culicid biodiversity in Minas Gerais, and in particular within semi-arid regions of the state.

KEYWORDS: Culicidae; Tropical dry forest (TDF); Conservation unit; Semi-arid; Minas Gerais.

INTRODUCTION

Mosquitoes (Diptera: Culicidae) are a group of insects that in their early stages develop in a variety of aquatic habitats, including permanent (i.e. rivers and lakes) and transient; transient habitats can include any receptacle that accumulates water, such as hollow trees, bromeliad tanks, fallen plant material, and even animal tracks[21].

Studies of Culicidae diversity in Brazil were mainly focused on rainforests in the southeastern and southern regions of the country, which coincide with the location of major national research centers. The Amazon rainforest is another important, well-studied region, primarily because of its significance for the transmission of several diseases, such as malaria and wild-type yellow fever[7]. However, the authors remain unsure of the diversity of mosquitoes in Brazilian regions with different climatic characteristics and forms of vegetation.

Despite the high diversity of plant and animal species in other biomes, such as the Cerrado (Savanna) and Caatinga (Semi-arid forest), there are very few studies of Culicidae diversity in these areas, and in particular, few in the transition zones between these biomes in northern Minas Gerais (MG). This region is primarily tropical dry forest (TDF), characterized by deciduous forest vegetation and a semi-arid climate, due to low humidity and low rainfall.

The last major survey of Culicidae in Minas Gerais was conducted in 1962 by MACIEL[16]. The author compiled his own data with data from literature, as well as from the former Department of Rural Endemic Diseases. With this, he created a list of the Culicidae in Minas Gerais and the municipalities where they were found, as well as the coordinates of the collection sites. Overall, 119 species of Culicidae were reported as occurring in 168 municipalities. The upper-middle area of the São Francisco region appears in this report due to a study in 1960 by ANDRADE & LEAL[1] on *Anopheles* in the São Francisco river, which contains two surveys done in the city of Manga in 1947 and 1954. Thereafter, the only published work in northern Minas Gerais was by GAMA *et al.*[13], in which the authors present a list of Anophelines collected in the municipality of Varzelândia.

The present study aims to conduct an inventory of the Culicid fauna in conservation units within a semi-arid region of the state of Minas Gerais, Brazil, in order to better understand the diversity of Culicidae in this region.

MATERIALS AND METHODS

Samples were collected within four conservation units administered by the State Forestry Institute (Instituto Estadual de Florestas - IEF). These areas are in the northern region of Minas Gerais, in the mid-São Francisco Valley, and are as follows: (1) the Mata Seca State Park MSSP (Parque Estadual da Mata Seca - PEMS) (14º48'36''S - 43º55'12''), located in the municipality of Manga; (2) the Lagoa do Cajueiro State

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Park - LCSP (Parque Estadual Lagoa do Cajueiro - PELC) (14º55'08''S - 43º56'23''W) and (3) the Jaíba Biological Reserve - JBR (Reserva Biológica de Jaíba) (15º3'57.81"S - 43º45'45.03"W), both located in the municipality of Matias Cardoso; and (4) the Serra Azul Biological Reserve - SABR (Reserva Biológica de Serra Azul) (15º11'32.20"S - 43º54'41.1"W), located in the municipality of Jaíba (Fig. 1).

As the study areas are located within a Caatinga-Cerrado transition zone, they contain fragments of tropical dry forest (TDF). These formations are broadly defined as having a vegetation type typically dominated by deciduous trees (at least 50% deciduousness during the dry season), with an average annual temperature ≥ 25 °C, total annual precipitation between 700 and 2,000 mm, and three or more dry months per year (precipitation < 100 mm/month[22]). According to the Köppen classification, regions with TDFs have a seasonal tropical climate (Aw) with an average annual temperature of 24.4 ºC and an average annual precipitation of 871 mm[2].

The Culicidae collections were carried out in 20 x 50 m plots, located within tropical dry forest fragments during the dry and rainy seasons between August 2008 and July 2012, on a total of 18 nights and across 504 hours of collections in the dry seasons, with the same sampling effort taking place in the wet seasons during the study period. Night trapping utilized two sampling methods, both beginning at dusk: one Shannon-type light trap exposed for a period of two hours and two CDC light traps exposed for a period of 12 hours per plot. A third sampling method consisted of "active collections" used to sample mosquitoes with daytime activity, and was performed once at each sample point for 45 minutes. Briefly, active collections consisted of using a manual vacuum to collect all mosquitoes landing on researcher's bodies prior to the attempted blood meal. Transportation and mounting techniques for mosquitoes were based on previous reports by FORATTINI[10] and CONSOLI & OLIVEIRA[6]. Specimens were taxonomically identified and incorporated into the entomological collection of the Laboratory of Ecology and Biological Control of Insects (Laboratório de Ecologia e Controle Biológico de Insetos - LECBI) at Montes Claros State University (Universidade Estadual de Montes Claros - Unimontes). Species identification was carried out using dichotomous keys by CONSOLI & OLIVEIRA[6], FARAN[9], FORATTINI[10] and LANE[15].

RESULTS

During the study period, a total of 11,219 mosquitoes were collected (11 genera and 45 species). There were 15 new records for Minas Gerais overall, and 26 new records for the semi-arid region of Minas Gerais (Table 1).

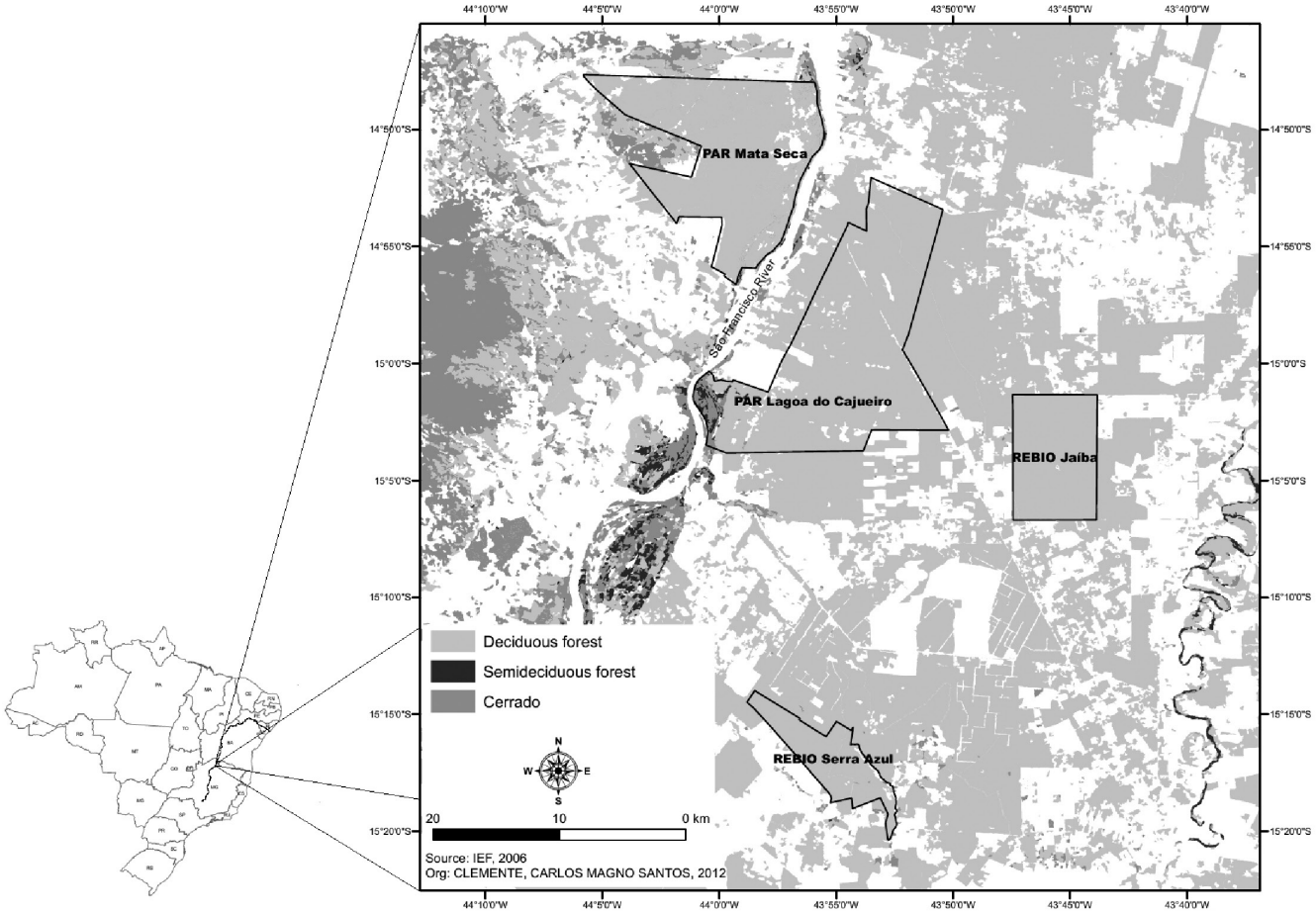

Fig. 1 - Map of the conservation units located in the northern region of the state of Minas Gerais, Brazil, where Culicidae were sampled in the period between August 2008 and July 2012 (215 × 279 mm; 300 × 300 DPI)

Table 1

Culicidae species sampled in the dry and wet seasons in the period between August 2008 and July 2012 in Mata Seca State Park (MSSP), Lagoa do Cajueiro State Park (LCSP), Jaiba Biological Reserve (JBR) and Serra Azul Biological Reserve (SABR), in the northern region of the state of Minas Gerais, Brazil

SPECIES	MSSP		LCSP		JBR		SABR		Total
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	
Anophelinae									
Anopheles (Nys.) *albitarsis* Lynch Arribalzaga, 1878	19	4	17	9	0	1	0	0	50
An. (Nys.) *argyritarsis* Robineau-Desvoidy, 1827	23	37	79	13	0	1	0	0	153
An. (Nys.) *braziliensis* (Chagas, 1907)	0	2	0	1	0	0	0	0	3
An. (Nys.) *darlingi* Root, 1926	53	76	8	16	0	0	0	0	153
An. (Nys.) *deaneorum* Rosa-Freitas, 1989 +	0	0	4	2	0	0	0	0	6
An. (Nys.) *evansae* (Brethes, 1926) +	0	0	0	1	0	0	0	1	2
An. (Nys.) *triannulatus triannulatus* (Neiva & Pinto, 1922)	33	27	2	3	0	0	0	0	65
An. (Nys.) Albimanus section/Oswaldoi Subgroup	4	5	0	1	2	0	0	0	12
Culicinae									
Tribe Aedomyiini									
Aedeomyia (Ady.) *squamipennis* (Lynch Arribalzaga, 1878)+	12	31	4	4	0	0	0	0	51
Tribe Aedini									
Aedes (How.) *fulvithorax* (Lutz, 1904)+	0	0	0	1	0	0	0	0	1
Ae. (Och.) *fulvus* (Wiedemann, 1828)	0	2	0	13	0	0	0	1	16
Ae. (Och.) *hastatus* Dyar 1922*+	0	1	0	3	0	0	0	0	4
Ae. (Och.) *scapularis* (Rondani 1848)	25	393	6	526	1	176	0	802	1,929
Ae. (Och.) *serratus* (Theobald 1901)	0	0	0	3	0	0	0	1	4
Ae. (Och.) *stigmaticus* (Edwards 1922)*+	0	134	0	207	0	1	0	0	342
Ae. (Och.) *taeniorhynchus* (Wiedemann 1821)	0	0	0	0	0	0	0	1	1
Ae. (Stg.) *aegypti* (Linnaeus 1762)	0	1	0	0	0	0	0	0	1
Haemagogus (Con.) *leucocelaenus* (Dyar & Shannon, 1924)+	0	0	0	2	0	0	0	0	2
Hg. (Hag.) *janthinomys* Dyar, 1921+	0	2	0	2	0	0	0	0	4
Hg. (Hag.) *spegazzinii* Brethés, 1912	0	2	0	0	0	0	0	2	4
Psorophora (Gra.) *cingulata* Fabricius, 1805	0	0	0	0	0	0	0	2	2
Ps. (Jan.) *albigenu* (Peryassu, 1908)*+	0	7	0	30	0	0	0	0	37
Ps. (Jan.) *discrucians* (Walker, 1856)*+	0	30	0	557	0	0	0	9	596
Ps. (Jan.) *ferox* (Von Humboldt, 1819)	0	6	0	63	0	0	0	3	72
Tribe Culicini									
Culex (Cux.) *ameliae* Casal, 1967*+	1	0	0	0	0	0	0	0	1
Cx. (Cux.) *bidens* Dyar, 1922*+	0	0	0	1	0	0	0	0	1
Cx. (Cux.) *habilitator* Dyar & Knab, 1906*+	0	1	0	0	0	0	0	0	1
Cx. (Cux.) *restuans* Theobald, 1901*+	0	1	0	0	0	0	0	1	2
Cx. (Cux.) *salinarius* Coquillett, 1904*+	0	0	0	0	0	0	0	1	1
Cx. (Cux.) *saltanensis* Dyar, 1928*+	0	0	0	0	0	1	0	0	1
Cx. (Cux.) *scimitar* Branch & Seabrook, 1959*+	0	1	0	2	0	0	0	0	3
Cx. (Mel.) *complexo Vomerifer*	2	0	0	0	0	0	0	0	2
Cx. (Mel.) *group Atratus*	1	0	0	0	0	0	0	0	1
Cx. (Mel.) *section Melanoconion*	0	0	0	0	0	0	7	0	7
Tribe Mansoniini									
Coquillettidia (Rhy.) *albicosta* (Peryassú, 1908)+	2	332	0	0	0	0	0	0	334
Cq. (Rhy.) *hermanoi* (Lane & Coutinho, 1940)*+	0	10	1	181	0	0	0	0	192
Cq. (Rhy.) *juxtamansonia* (Chagas, 1907)	0	0	0	1	0	0	0	0	1
Cq. (Rhy.) *lynchi* Shannon 1931*+	0	0	0	0	0	2	0	0	2

Table 1

Culicidae species sampled in the dry and wet seasons in the period between August 2008 and July 2012 in Mata Seca State Park (MSSP), Lagoa do Cajueiro State Park (LCSP), Jaiba Biological Reserve (JBR) and Serra Azul Biological Reserve (SABR), in the northern region of the state of Minas Gerais, Brazil (cont.)

SPECIES	MSSP		LCSP		JBR		SABR		Total
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	
Cq. (Rhy.) *nigricans* (Coquillett, 1904)	7	810	0	38	0	0	0	0	855
Cq. (Rhy.) *venezuelensis* (Theobald, 1912)	9	598	0	116	0	0	0	1	724
Mansonia (Man.) *humeralis* Dyar & Knab 1916+	65	400	228	510	0	2	0	1	1,206
Ma. (Man.) *indubitans* Dyar & Shannon 1925+	3	26	730	113	0	1	0	2	875
Ma. (Man.) *pseudotitillans* (Theobald, 1901)+	24	401	0	9	0	0	0	0	434
Ma. (Man.) *titillans* (Walker, 1848)	161	1,352	508	1,010	3	0	0	6	3,040
Tribe Uranotaeniini									
Uranotaenia (Ura.) *geometrica* Theobald, 1901	0	0	0	2	0	0	0	0	2
Ur. (Ura.) *lowii* Theobald 1901*+	0	0	1	0	0	0	0	1	2
Ur. (Ura.) *pulcherrima* Lynch Arribalzaga 1891*+	0	0	0	2	0	0	1	0	3
Tribe Sabethini									
Limatus paraensis (Theobald 1903)	0	0	0	17	0	0	0	0	17
Sabethes (Pey.) *undosus* (Coquillett, 1906)+	0	1	0	0	0	0	0	0	1
Total	444	4,693	1,589	3,459	6	185	8	835	11,219

* *N*ew record to the Minas Gerais State. +new record to the semi-arid region of Minas Gerais.

DISCUSSION

Of all the collected specimens, 8,170 (73%) were characterized by their use of permanent breeding habitats (e.g. ponds, marshes, river backwaters and puddles) for their larval and pupal (immature) stages; these individuals represented Anophelinae subfamily and Mansoniini, Aedomyiini tribes and, in some cases, Culicini. The remaining 27% (3,040 specimens) were characterized by their use of temporary breeding habitats (e.g., puddles, hollow bamboo, bromeliads and other phytotelmata) in their larval and pupal stages, representing primarily Aedini, Uranotaeniini and Sabethini tribes.

Mosquito species belonging to the Mansoniini tribe were the most abundant (68.3%), of which the species *Mansonia titillans* alone accounted for 27.10% of all mosquitoes sampled in the study. Mosquitoes of the Aedini tribe were the second most abundant group of all mosquitoes collected (26.87%), with *Aedes scapularis* as the dominant species within the tribe (17.19%). Among the *Anopheles* species collected, *Anopheles darlingi* was the most abundant and amounted to 1.36% of all mosquitoes sampled.

The large percentage of mosquito species using permanent reservoirs might be related to the relatively long dry periods, which are characteristic of the study area. Prolonged droughts can have a damaging effect on the viability of Aedini mosquitoes' eggs[24] and can negatively affect the nutritional quality of the detritus found in temporary breeding habitats[4]. Despite the long dry periods, the community of mosquitoes manages to survive, mainly using the vegetation surrounding the ponds located in PEMS and PELC.

The large abundance of mosquitoes within the Mansoniini tribe can be explained by the influence of ponds located on the banks of the São Francisco River, located in the MSSP and LCSP. Even in dry seasons, these ponds act as major breeding grounds for Mansoniini mosquitoes in the larval and pupal stages as they contain lots of aquatic vegetation, the aerenchyma of the roots providing the mosquitoes with oxygen[10]. Some Mansoniini mosquitoes, such as *Coquillettidia venezuelensis,* are involved in the transmission of arboviruses, such as Eastern equine encephalitis virus (actual vectors) and Oropouche virus (potential vectors)[10]. In addition, *Ma. titillans* have been found to be naturally infected with the Venezuelan equine encephalitis virus. Thus, the large abundance of mosquitoes of the genus *Mansonia* in the conservation units sampled could potentially impact wild bird conservation, as these mosquitoes are ornithophilic and can transmit avian malaria[14,26].

The high abundance of *Aedes scapularis* was probably related to the vegetational structure of the study area, which is in the process of natural regeneration from successive anthropogenic pressures, such as agriculture and livestock farming[17]. These environments provide ideal conditions for the establishment of *Ae. scapularis* populations, as these mosquitoes have a marked tendency to invade artificially modified environments[8,11,12]. Furthermore, the larval and pupal stages of *Ae. scapularis* develop in temporary ground pools formed by rainfall, and are comparable to those known to exist in environments in the initial stages of natural regeneration[5,10].

At least 15 viruses have been isolated from *Ae. scapularis,* including the Rocio virus, Yellow fever virus, and Venezuelan equine encephalitis virus; this species may also be a vector of Bancroftian filariasis[18,20]. VASCONCELOS *et al.*[27] isolated a strain of Yellow fever virus from field-captured *Ae. scapularis*. Previously, only experimental laboratory infections had been reported in this species. Considering the ecological and epidemiological characteristics reported for this species, these mosquitoes can be a potential bridge between wild arboviruses and human populations in this region, given the current state of anthropogenic modifications of the study region.

Mosquitoes of the *Psorophora* genus were the most abundant Aedini after *Ae. scapularis*; this might be explained by the fact that these types of mosquitoes share the same breeding habitats[3,19,25]. Although *Psorophora* have been found to carry some types of infection in nature, mosquitoes of this genus are not considered epidemiologically significant vectors. These mosquitoes are, however, treated as potential incidental vectors of disease due to some of their behavioral characteristics, such as eclecticism in the choice of blood host and exophilic behavior[10].

The abundance of *An. darlingi* recorded deserves particular attention, as this species is the main vector of malaria parasites in Brazil and is widely distributed across South America[23]; additionally, these mosquitoes have an increased capacity for taking blood meals within and around residential regions[6]. Although *Anopheles argyritarsis* and *Anopheles triannulatus* are not the primary vectors of the *Plasmodium* species responsible for malaria, these species are of great epidemiological interest because of their high abundance and anthropophilic nature[6].

The abundance of new Culicid records for Minas Gerais State, and for the semi-arid region of the state, indicates that studies of mosquito communities in forest remnants are still required, especially with regards to the development and maintenance of support programs aimed at the prevention of disease transmission to humans and other animals.

RESUMO

Inventário de mosquitos (Diptera: Culicidae) em unidades de conservação em florestas tropicais secas brasileiras

No Brasil, a maior parte dos estudos relacionados à família Culicidae se concentram em regiões de florestas úmidas, existindo uma lacuna no conhecimento da diversidade destes mosquitos em regiões com características climáticas e vegetacionais diferentes. O objetivo desse trabalho foi inventariar a fauna de culicídeos em unidades de conservação do semi-árido de Minas Gerais, visando assim contribuir para o conhecimento da diversidade de Culicidae desta região. O estudo foi realizado em quatro unidades de conservação localizadas na região norte do estado de Minas Gerais, Brasil, área representada por fragmentos de Floresta Tropical Seca (FTS). Foram utilizados três métodos de coleta: armadilha do tipo Shannon, armadilha luminosa do tipo CDC e coleta ativa. Durante o período de agosto de 2008 a julho de 2012 foi coletado um total de 11.219 espécimes de mosquitos, distribuídos em 11 gêneros e 45 espécies. Foram registrados 15 novos registros de mosquitos para o estado de Minas Gerais e 26 novos registros para a região do semi-árido de Minas Gerais. O elevado número de novos registros de Culicidae na região demonstra a importância de estudos de inventário para o aumento do conhecimento da biodiversidade de culicídeos em Minas Gerais, e em particular a região do semi-árido do estado.

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