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Culicidae (Diptera: Culicomorpha) from the central Brazilian Amazon: Nhamundá and Abacaxis Rivers

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ABSTRACT. Mosquito fauna (Culicidae) from remote areas along the geographical limits of the State of Amazonas were assessed by employing CDC, Shannon, Malaise and Suspended traps, together with net sweeping and immature collections. Two hundred and six collections were performed in seven localities along the Nhamundá and Abacaxis Rivers, State of Amazonas, Brazil, during May and June 2008. The northernmost locality was 120 km from Nhamundá, whereas the southernmost locality was 150 km from the mouth of the Abacaxis River. The 5,290 mosquitoes collected are distributed in 16 genera, representing 109 different species, of which eight are new distributional records for the State of Amazonas. Furthermore, there are nine morphospecies which may represent undescribed new taxa, five of which are also new records for the State of Amazonas. *Culex* presented the highest number of species and the largest number of individuals. *Anopheles*, which represents 3% of the total sample, had the second highest number of species, followed by *Wyeomyia*. *Psorophora* and *Aedes*, represent the third and fourth largest number of individuals. The most abundant species was *Cx.* (*Mel.*) *vaxus* Dyar, 1920 followed by *Cx.* (*Mel.*) *eknomios* Forattini & Sallum, 1992, *Cx.* (*Cux.*) *mollis* Dyar & Knab, 1906, *Cx.* (*Mel.*) *theobaldi* Lutz, 1904, and *Cx.* (*Cux.*) *declarator* Dyar & Knab, 1906. The epidemiological and ecological implications of mosquito species found are discussed and are compared with other mosquito inventories from the Amazon region. The results presented represent the largest standardized inventory of mosquitoes of the Nhamundá and Abacaxis rivers, with the identification of 118 species level taxa distributed in seven localities, within four municipalities (Nhamundá, Maués, Borba, Nova Olinda do Norte), of which we have only few or no records in the published literature.

KEY WORDS. Amazonia; distribution; mosquitoes.

There are about 3,523 species of mosquitoes (Culicidae) described throughout the world (Harbach 2012). Mosquitoes have a worldwide distribution with at least 553 species present in the Neotropical region, of which 468 are recorded from Brazil (Gaffigan *et al.* 2012). Records of geographical distribution are essential to improve our knowledge of the systematics of mosquitoes, as well as the need for the correct identification of species in studies of biodiversity, ecology and vector incrimination. In general, the knowledge of the biodiversity of Culicidae is of public health interest, since it enables a better understanding of the dynamics of transmission of infectious agents and the role of mosquito species as vectors, facilitating the adoption of control measures.

Because of its extensive and complex geographical structure, the Amazon region has many remote areas, such as the basins of the Nhamundá and Abacaxis rivers, located north and south of the Amazon River along the eastern border of the Brazilian State of Amazonas, where the Culicidae fauna is unknown. Unfortunately, very little is known about the geographic distribution of mosquitoes in the State of Amazonas. Cerqueira (1961), in a pioneering work, using information gathered from the collections of the defunct *Serviço Nacional de Febre Amarela* (National Yellow Fever Service) and material collected by the *Instituto Nacional de Pesquisas da Amazônia* (National Institute of Amazonian Research), reported the presence of 148 species in 24 locations within the State of Amazonas. Later, several papers were published on the geographical distribution of Culicidae in the Amazon, using information gathered from bibliographical references and material from the Entomology Museum of the *Centro de Pesquisas René Rachou* (FIOCRUZ) (René Rachou Research Center), adding new locality records for the state, where the number of known species increased to 175 in 114 locations representing 61% of the state's municipalities (Xavier & Mattos 1976). Unfortunately, after Xavier & Mattos (1976), there has not been any new publication compiling and updating the distribution records of species which can be found in more recent publications. Most of these new records of distribution are found in publications resulting from inventories (Barbosa *et al.* 2008, Hutchings *et al.* 2002, 2005, 2008, 2010, 2011, Suárez-Mutis *et al.* 2009) and as a result of the description of new species (Forattini & Sallum 1992, Sallum & Hutchings 2003, Sallum *et al.* 1997).

It should be noted that many of the published records are not results of collections made with the purpose of studying the entire mosquito community, but mainly had epidemiological objectives (Cerqueira 1961, Deane 1947). Therefore, any list of species prepared for a given location which is based on published records may be incomplete and/or biased. For example, after collecting 119 species in the Jau National Park, 25% (30 species) were new records for the State of Amazonas (Hutchings *et al.* 2005) and of 145 species collected north of Manaus (Hutchings *et al.* 2011), 16% (23 species) are also new records for the State of Amazonas, including seven new records for Brazil. Outside of being biased, the geographical distribution of published records is still unrepresentative given the low coverage of the municipalities. Although the coverage includes 61% of the municipalities within the State of Amazonas, the sampled area of each municipality is still very small.

It is important to consider that an increase in the knowledge of the mosquito fauna of the Amazon region will permit us to obtain basic information of the faunal diversity, distribution and variety of ecosystems where mosquitoes occur, thus providing basic knowledge for studies on the control of diseases which affect humans and animals, whose infectious agents are transmitted by mosquitoes. In this work, we present the first results of mosquito collections from remote regions located near the political boundaries of the State of Amazonas, as part of the project "*Amazonas: Diversidade de insetos ao longo de suas fronteiras*" of the Programa de Apoio a Núcleos de Excelência (FAPEAM-CNPq).

Therefore, with the objective of serving as a base inventory for future surveys of Culicidae from the Amazon, the mosquito species collected inside the riparian and *terra firme* forests along the basins of the Nhamundá and Abacaxis rivers, Amazonas, Brazil, are reported herein.

MATERIAL AND METHODS

A mosquito inventory, conducted during a river expedition in areas near the eastern border of the State of Amazonas, Brazil (Fig. 1), includes collections of mosquitoes from seven different localities: two localities along the Nhamundá River, Municipality of Nhamundá (between 01°35'S, 057°37'W and 01°53'S, 057°03'W); and five localities along the Abacaxis River, including the Municipalities of Maués, Borba and Nova Olinda do Norte (between 05°15'S, 058°41'W and 04°28'S, 058°33'W). These localities are characterized by having most of their area covered by dense upland (*terra firme*) ombrophilous forests with low plateaus, together with riparian rain forests having dense alluvial and lowland vegetation (*Floresta Ombrófila Densa Aluvial e de Terras Baixas*) along the rivers, intermixed with areas of transition including Amazonian white sand (*campinarana*) and floodplain (*varzea*) forests. The tropical rainforest climate is warm and wet, characterized by being constantly humid, with temperature and precipitation with little annual variation. Based on climatic data from Parintins and Maues (RADAMBRASIL 1976), the

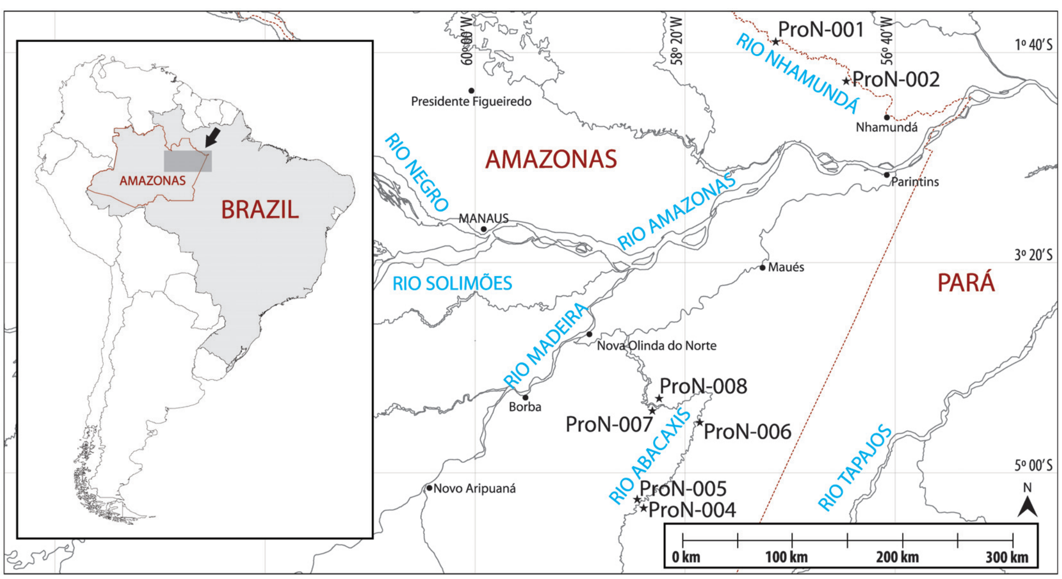

Figure 1. Localities sampled along the Nhamundá and Abacaxis Rivers, State of Amazonas, Brazil (The stars indicate the collecting locations described in Table I).

region has an annual relative humidity of 86% and a mean annual temperature of 26°C. A shorter dry season occurs from July to November with the lowest monthly precipitation being less than 50 mm along the Nhamundá River and over 150 mm along the Abacaxis River. The rainy season occurs between December and June, with the maximum precipitation in April. For the Nhamundá basin the mean annual precipitation is 1,750 mm, while the Abacaxis basin is greater than 2,750 mm.

Located in the far eastern region of the State of Amazonas, there are many difficulties in accessing the collection locations because of the long distance from urban centers. The most remote locality surveyed along the Nhamundá River is 240 km from Parintins and 630 km from Manaus, while the localities along the Abacaxis River are 360 km from Maués and 530 km from Manaus. The region, with a very low demographic density, only has small settlements which occupy marginal areas along the rivers. The main means of transport is by boat.

Mosquitoes specimens were mostly collected inside the riparian forest along existing and/or newly created trails, perpendicular to the river banks, and within continuous upland *terra firme* forest using a variety of capture methods including: CDC traps with different types of lighting (incandescent lamp (CDC) or ultraviolet fluorescent tube (UV CDC)); flight intercept traps (Malaise, Shannon, Suspended); and sweeping with nets. The CDC traps were installed every 50 m along trails, placed at 1, 10, 15 or 20 m above the ground, and were activated at dusk for a period of 12 hours, between 18:00 and 06:00 h. The Shannon traps, placed within small open understory areas, using an internal light source for attraction and a portable battery powered aspirator for capturing specimens, were used between 18:00 and 21:00 h. The 6 m long Malaise flight intercept traps, also placed within small open understory areas, were used for periods of up to three days and the Suspended flight intercept traps were hung one meter above the water level, along river margins, or at tree canopy level, also for periods of up to three days. Each sweeping collection, using entomological nets, was performed during a minimum of two hours at each location. Immature mosquitoes were collected from breeding sites found along trails, in the same areas where adults were captured. The immature mosquitoes were reared for the purpose of obtaining adult males and females, associated with larval and pupal exuviae. These reared specimens were mostly used to obtain a more accurate identification of adult female specimens captured using other methods.

Adult and immature mosquitoes were captured, preserved and mounted following techniques detailed by Belkin *et al.* (1967). Specimens were identified in the laboratories at INPA in Manaus, and were confirmed at the Laboratório de Sistemática e Ecologia de Culicidae (LASEC), of the Faculdade de Saúde Pública (FSP/USP), in São Paulo and in the Laboratório de Transmissores de Hematozoários of the Instituto Oswaldo Cruz (IOC), in Rio de Janeiro, using the identification keys in Lane (1953a, b), Forattini (1965a, b, 2002), Zavortink (1972, 1979), Arnell (1973), Valencia (1973), Berlin & Belkin (1980), Sallum & Forattini (1996), as well as the Pecor *et al*. (1992) catalog for *Culex* (*Melanoconion*). Whenever possible, anatomical characteristics of the male genitalia were examined to confirm the identifications of both females and males. The collected material will be deposited in the Coleção de Invertebrados of the Instituto Nacional de Pesquisas da Amazônia (INPA-Manaus), in the Coleção Entomológica de Referência of the Faculdade de Saúde Pública, Universidade de São Paulo (FSP/USP) and in the Coleção de Culicídeos of the Instituto Oswaldo Cruz (FIOCRUZ). The collection and specimen data was digitized, stored, archived and organized using the relational database structure provided by the Biota software version 2.04 (Colwell 2012).

RESULTS

A total of 206 collections distributed in seven locations along the Nhamundá and Abacaxis Rivers, in the State of Amazonas, from May 14 to June 6, 2008, resulted in the capture of over 5,000 mosquitoes (Table I). Each collection corresponds to the capture yield of a trap (i.e. CDC, CDC UV, Shannon, Malaise, and Suspended) or method (i.e. sweeping,

Table I. Collections of mosquitoes distributed in seven localities along the Nhamundá and Abacaxis Rivers in the State of Amazonas, Brazil.

Locality	Locality name*	Municipality	Coordinates	Number of collections	Number of specimens
ProN-001	Areia, Igarape do Areia (LM), Rio Nhamundá (RM)	Nhamundá	01°35’22”S, 57°37’06”W	55	674
ProN-002	Cuipiranga, Lago do Aburi, Rio Nhamundá (RM)	Nhamundá	01°53’42”S, 57°03’25”W	43	259
ProN-004	Picada Pirarara, Rio Abacaxis (RM)	Maues	05°15’09”S, 58°41’52”W	26	512
ProN-005	Picada Borba, Rio Abacaxis (LM)	Borba	05°13’19”S, 58°41’22”W	20	659
ProN-006	Pacamiri, Rio Abacaxis (RM)	Maues	04°35’49”S, 58°13’14”W	29	1,118
ProN-007	Paxiuba, Rio Abacaxis (LM)	Borba	04°29’00”S, 58°34’14”W	32	2,044
ProN-008	Paxiuba, Rio Abacaxis (RM)	Nova Olinda do Norte	04°28’36”S, 58°33’46”W	1	24
Total				206	5,290

* (LM) left margin of the basin; (RM) right margin of the basin.

immature rearing) (Table II). The CDC traps were used during 1,200 trap-hours and the CDC UV during 744 trap-hours. The Shannon traps were used in eight collections, totaling 28 trap-hours. The 6m Malaise flight intercept traps were used during 15 trap-days and the Suspended traps during nine trap-days. The net sweeping collections were done during 40 hours. A total of eight immature collections were performed in different habitats: Bromeliaceae leaf axils (three samples); lakes and streams (3); in a tree hole; and in a *Bertholletia* pixidium. More specific information on the sampling effort for each locality is presented in Table II.

Of the 5,290 specimens captured, 5,231 were identified and are distributed in 16 genera, representing 118 different taxa (among species and morphospecies) (Appendix 1). The morphospecies (identified as near F#) are similar to a known species, but it is believed that some may represent undescribed new taxa. Some identification could not be exact because of the absence of males, whose genitalia usually possess anatomical features that allow the specific diagnosis. These individuals were identified as morphotypes, indicating the species to which they are most similar.

Unfortunately, among the mounted, sorted and examined material, it was not possible to identify 1,815 specimens (≈ 34%) to the species level for several reasons: either there are no known characters to separate female individuals of different species or the characters used to separate these species were damaged. For some of these individuals it was only possible to identify to genus level because the characters which are used for identification are damaged and/or lost, and the rest of the collected material was recognized to subgeneric or informal taxonomic group (sections or groups) level (shown with the prefix "gr.", "sG." or "sec." or the suffix "sp." in Appendix 1). Most of the individuals that could not be identified to species level are females (1790 H" 98%) and belong to the genus *Culex* (91%) (Appendix 1). It is interesting to note that only 13% of the specimens collected in this inventory were males.

Culex presented the highest number of species (45 H" 42%) and the largest number of individuals (4,653 H" 89%). The genus *Anopheles*, which represents 3% of the total sample (166 specimens), had the second highest number of species (13 H" 12%), followed by *Wyeomyia* with 11 species (H" 10%), and less than 1% of individuals. *Psorophora* and *Aedes, respectively* with 9 and 8 species each (H" 7%), represent the third largest (178 H" 3%) and the fourth largest number of individuals (90 < 2%).

The most abundant species was *Culex* (*Mel.*) *vaxus* Dyar, 1920 (587 individuals collected, representing 17% of the material identified to species level) followed by *Cx.* (*Mel.*) *eknomios* Forattini & Sallum, 1992, *Cx.* (*Cux.*) *mollis* Dyar & Knab, 1906, *Cx.* (*Mel.*) *theobaldi* Lutz, 1904, and *Cx.* (*Cux.*) *declarator* Dyar & Knab, 1906 (with 481, 456, 415 and 255 individuals, respectively). The five most abundant species (<5% of the recorded species) represent 66% of specimens identified to the species level.

Table II. Method of capture, sampling effort and number of mosquitoes collected along the Nhamundá and Abacaxis Rivers in the State of Amazonas, Brazil.

Method of capture	Species/Method Total number *Exclusive number*	Number of specimens *Sampling effort*		
		Total	Nhamundá River	Abacaxis River
CDC trap	51	2,573	152	2,421
	7	*100c:1,200h*	*44c:528h*	*56c:672h*
CDC (UV) trap	62	1,777	299	1478
	12	*62c:744h*	*34c:408h*	*28c:336h*
Shannon Trap	31	406	155	251
	3	*8c:28h*	*5c:17h*	*3c:11h*
Net sweeping	51	376	219	157
	17	*20c:40h*	*9c:18h*	*11c:22h*
Malaise Trap	18	56	41	15
	4	*5c:15d*	*3c:9d*	*2c:6d*
Suspended Trap	18	69	48	21
	6	*3c:6d*	*1c:3d*	*2c:3d*
Immature collections	9	33	19	14
	4	*8c*	*2c*	*6c*
Total	118	5,290	933	4,357
	53	*206c*	*98c*	*108c*

The values in italics indicate the sampling effort for the method used: number of collections (#c); trap-hours (#h); or trap-days (#d).

Among the 110 species identified, there are eight new species distribution records for the State of Amazonas: *Psorophora (Jan.) discrucians* (Walker, 1856); *Culex* (*And.*) *luteopleurus* (Theobald, 1903); *Culex* (*Mel.*) *rooti* Rozeboom, 1935; *Culex* (*Mel.*) *trigeminatus* Clastrier, 1970; *Culex* (*Mcx.*) *aureus* Lane & Whitman, 1951; *Onirion brucei* (Del Ponte & Cerqueira, 1938); *Wyeomyia* (*Spi.*) *aningae* Motta & Lourenço, 2005; and *Wyeomyia surinamensis* Bruijning, 1959. There are also 203 specimens of at least nine morphospecies (marked as near F # in Appendix 1), of which five also represent new geographical records for the State of Amazonas. These morphospecies, which probably represent species not yet described, belong to three different genera. *Aedes* (*Ochlerotatus*) has a total of four specimens of two morphotypes: *Ae*. (*Och.*) near *pectinatus* F1 and *Ae*. (*Och.*) near sG Infirmatus F1. *Culex* (*Melanoconion*) has 196 specimens of six morphotypes: *Cx*. (*Mel.*) near *creole* F1, *Cx*. (*Mel.*) near *eastor* F1, *Cx*. (*Mel.*) near *silvai* F1, *Cx*. (*Mel.*) near *vaxus* F1, *Cx*. (*Mel.*) near *vaxus* F3 and *Cx*. (*Mel.*) near *venezuelensis* F1. *Wyeomyia* (*Hystatomyia*) has two specimens of one morphotype: *Wy*. (*Hys.*) near *baltae* F1. Among the nine morphotypes identified (*Anopheles* (*Nys.*) *goeldi*/***dunhami**, Anopheles* (*Nys.*) *konderi*/*oswaldoi, Anopheles* (*Ste.*) *nimbus*/*thomasi*, *Aedes* (*Och.*) ***hastatus***/*oligopistus, Aedes* (*Och.*) *serratus*/***nubilus**, Culex* (*Ads.*) ***clastrieri***/*guyanensis, Culex* (*Car.*) *urichii*/***anduzei***, *Culex* (*Cux.*) ***coronator*/*usquatus*** *and Culex* (*Cux.*) *mollis*/*declarator*) there are seven species (indicated in bold above) which could potentially also increase the number of species recorded within each sampled locality.

Together, the nocturnal collecting methods (CDC, CDC-UV and Shannon Traps) were responsible for 90% of the captured mosquitoes, of which the CDC traps (with a total combined sampling effort of 162 trap-nights) were responsible for more than 83%. Net sweeping accounted for 7%, followed by the Suspended and Malaise flight intercept traps, with 1.3% and 1% of the specimens, respectively (Table II). Both types of CDC traps together were responsible for collecting 62% (73) of the species level taxa, of which the CDC-UV trap alone collected 53% of the species level taxa. The adult specimens of *Aedeomyia*, *Orthopodomyia* and *Uranotaenia* were only collected at night (CDC, CDC-UV and Shannon), while *Haemagogus* was only collected during the day and *Onirion* was only registered by rearing larvae. The methods of capture for each taxon can be seen in the final columns of Appendix 1. Net sweeping, and the CDC type traps combined, were responsible for the highest number of species which were only and exclusively collected with a specific method of capture, although every method did collect exclusive species (see details in Table II). The diurnal mosquitoes are not equally represented in this inventory, compared to the nocturnal mosquitoes because the sampling effort was greater for the nocturnal collecting methods.

Of the 118 different species level taxa identified during this inventory, 48 (41%) were collected in both river basins, while 29 species (24%) were found only along the Nhamundá River and 41 species (35%) were only found along the Abacaxis River (Appendix 1). The results of the mosquito inventory for each separate river basin are presented below.

Nhamundá River

The inventory along the Nhamundá river basin, sampled from May 16 to 19, includes specimens from 98 collections in two localities (Table I), resulting in 933 mosquitoes from 15 genera, representing 77 different taxa identified to species level (between species and morphospecies) (Appendix 1). It was not possible to identify 256 specimens (H” 27%) to the species level for the reasons previously discussed. For this basin, the sampling effort included 528 CDC trap-hours, 408 CDC (UV) trap-hours, 17 Shannon trap-hours, 9 Malaise trap-days, 3 Suspended trap-days, 18 net sweeping hours and two immature collections (in a *Bertholletia* pixidium and a Bromeliaceae leaf axil) (Table II).

In the Nhamundá River basin, the genus *Culex* presented the highest number of species (26 H” 38%) and the largest number of individuals (712 H” 77%). The genus *Wyeomyia*, which represents 4% of the total sample (34 specimens), had the second highest number of species (11 H” 16%), followed by *Psorophora* with only seven species represents the second largest number of specimens (71 H” 8%). *Anopheles* had 6 species (H” 9%), and less than 4% of the individuals, while *Aedes* with five species had the third largest number of individuals (45 < 5%). The most abundant taxon was the morphospecies *Culex* (*Mel.*) near *vaxus* F3 (142 individuals collected, representing 23% of the specimens identified to species level) followed by *Cx*. (*Mel.*) *vaxus* Dyar, 1920, *Cx*. (*Mel.*) *bequaerti* Dyar & Shannon, 1925, *Psorophora* (*Jan.*) *ferox* (Humboldt, 1819), and *Cx*. (*Cux.*) *mollis* Dyar & Knab, 1906 (with 122, 64, 38 and 29 individuals, respectively). The five most abundant species (<7% of the recorded species) represent 64% of specimens identified to the species level.

Among the 70 species, collected along the Nhamundá River, there are six new species distribution records for the state of Amazonas. There are also 159 specimens of at least seven morphospecies (9% of the species level taxa), of which four represent new geographical records for the State of Amazonas. These morphospecies, which probably represent species not yet described, belong to three different genera: *Ae*. (*Och.*) near sG Infirmatus F1, *Cx*. (*Mel.*) near *creole* F1, *Cx*. (*Mel.*) near *silvai* F1, *Cx*. (*Mel.*) near *vaxus* F1, *Cx*. (*Mel.*) near *vaxus* F3, *Cx*. (*Mel.*) near *venezuelensis* F1 and *Wy*. (*Hys.*) near *baltae* F1.

Abacaxis River

The inventory along the Abacaxis river basin, sampled from May 26 to June 4, includes specimens from 108 collections in five localities (Table I), resulting in 4,357 mosquitoes, from 15 genera, representing 89 different taxa identified to species level (including species and morphospecies) (Appendix 1). It was not possible to identify 1558 specimens (H” 36%) to the species level for the reasons previously discussed. For this basin, the sampling effort included 672 CDC trap-hours, 336

CDC (UV) trap-hours, 11 Shannon trap-hours, six Malaise trap-days, three Suspended trap-days, 22 net sweeping hours and six immature collections (in lakes and streams (three samples), in two Bromeliaceae leaf axils, and in a tree hole (Table II).

In the Abacaxis River basin, *Culex* presented the highest number of species (37 H" 44%) and the largest number of individuals (3,941 H" 92%). *Anopheles*, which represents 3% of the total sample (136 specimens), had the second highest number of species (13 H" 15%), followed by *Psorophora* and *Aedes* with six species (H" 7%) each, representing the third largest (107 H" 3%) and the fourth largest number of individuals (45 = 1%). The most abundant species was *Cx*. (*Mel*.) *eknomios* Forattini & Sallum, 1992 (479 individuals collected, representing 18% of the material identified to species level) followed by *Culex* (*Mel*.) *vaxus* Dyar, 1920, *Cx*. (*Cux*.) *mollis* Dyar & Knab, 1906, *Cx*. (*Mel*.) *theobaldi* Lutz, 1904, and *Cx*. (*Cux*.) *declarator* Dyar & Knab, 1906 (with 465, 427, 392 and 245 individuals, respectively). The five most abundant species (<6% of the recorded species) represent 74% of specimens identified to the species level.

Among the 84 species, collected along the Abacaxis River, there are three new species distribution records for the State of Amazonas. There are also 43 specimens of at least five morphospecies (H"6%), of which two represent new geographical records for the State of Amazonas. These morphospecies, which probably represent species not yet described, belong to two different genera: *Ae*. (*Och*.) near *pectinatus* F1, *Cx*. (*Mel*.) near *eastor* F1, *Cx*. (*Mel*.) near *silvai* F1, *Cx*. (*Mel*.) near *vaxus* F1, and *Cx*. (*Mel*.) near *vaxus* F3.

DISCUSSION

Among the 118 species level taxa collected in this inventory, there are 13 (11%) new geographical distribution records for the State of Amazonas. Other mosquito surveys from upland terra firme sites have similar results: of the 145 species collected, north of Manaus, 16% (23 species) were new records for the State of Amazonas (Hutchings *et al.* 2011); of the 119 species collected in the Jau National Park, 25% (30 species) were new records (Hutchings *et al.* 2005); and of the 44 species recorded in Querari, 27% (12 species) were also new records for the state (Hutchings *et al.* 2002). We found no previously published mosquito distributional records for the municipalities of Nhamundá and Nova Olinda do Norte. Therefore, the results of this inventory represent the first published report of mosquito taxa for these municipalities.

Epidemiologically, the presence of Anophelines may be important because this genus includes *Plasmodium* vector species, which cause malaria in humans. Within the *Anopheles*, it is worth noting the presence of *Anopheles* (*Nys*.) *konderi s.l.*, *An*. (*Nys*.) *oswaldoi s.l.* and *Anopheles* (*Nys*.) *triannulatus*, and absence of *An*. (*Nys*.) *darlingi* Root, 1926 and any species of the *An*. (*Nys*.) *albitarsis* complex. *Anopheles* (*Nys*.) *konderi s.l.*, *An*. (*Nys*.) *oswaldoi s.l.* and *Anopheles* (*Nys*.) *triannulatus* are considered secondary vectors, but they can take the role of local or regional primary vectors (Forattini 2002). Considering that *Anopheles* (*Nys*.) *konderi s.l.* and *An*. (*Nys*.) *oswaldoi s.l.* were demonstrated to be species complexes (Motoki *et al.* 2009, Sallum *et al.* 2008), the vector status of each species needs to be determined in further studies conducted in areas of malaria transmission where species of these complexes are present. Additionally, the absence of *An*. (*Nys*.) *darlingi* and also of species of the *An*. (*Nys*.) *albitarsis* complex may be indicative of an undisturbed natural environment. In several studies conducted inside pristine areas of the State of Amazonas, no specimens of *An*. (*Nys*.) *albitarsis s.l.* and only a few specimens of *An*. (*Nys*.) *darlingi* were found. For example, only seven *An*. (*Nys*.) *darlingi* specimens (2% and 4% of the Anophelines, respectively) were collected in both the Jau National Park (Hutchings *et al.* 2005) and in the Juami-Japura Ecological Station (Hutchings *et al.* 2010), while only one *An*. (*Nys*.) *darlingi* specimen (<0.4%) was found in areas north of Manaus (Hutchings *et al.* 2011). In contrast, *An*. (*Nys*.) *darlingi* can be the most prevalent species inside deforested areas of the Amazon region (Castro *et al.* 2006), whereas species of *An*. (*Nys*.) *albitarsis* complex can become more frequent depending on the land use (Conn *et al.* 2002).

Furthermore, there are *Culex* species which are potential vectors of arboviruses. For example, *Cx. gnomatos*, the second most common *Culex* species in these samples, is highly susceptible to infection by enzootic (ID and IE) and epizootic strains (IAB and IC) of the Venezuelan Equine Encephalitis Virus (VEEV) (Turell *et al.* 2000). It is worth mentioning that *Cx. pedroi*, also a common species in these collections, is considered a potential enzootic vector of the Eastern Equine Encephalitis Virus (EEEV), in Brazil, as well as of the VEEV and other arboviruses (Galindo & Srihongse 1967, Galindo *et al.* 1966, Srihongse & Galindo 1967). Moreover, it is interesting to note that Aitken (1972) observed that *Cx. portesi* may be involved in the of epizootic and enzootic transmission cycles of the Mucambo virus. *Cx. spissipes* is a potential vector of the Bimiti, Caraparu, Oriboca and Itaqui viruses, of the Bunyaviridae family and of the VEEV III-B subtype (Shope *et al.* 1988, Walton & Grayson 1988).

Considering the number of specimens and/or species resulting from the different methods of capture and sampling efforts of this inventory (Table II), future mosquito surveys should give priority to the use of CDC type traps and net sweeping in order to maximize collecting results, when time and field resources are limited.

This mosquito inventory is part of a larger entomological inventory of different locations within remote and sparsely populated areas near the border regions of the State of Amazonas which also resulted in the collection of a large number of other insects, including Lepidoptera (Casagrande *et al.* 2012). The information presented here represents the largest standardized mosquito inventory ever executed, within the Nhamundá and Abacaxis river basins, with the identification of 118 taxa distributed in seven different locations within four different counties (Nhamundá, Maués, Borba, Nova Olinda do Norte), of which few or no geographical records have been previously published.

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Appendix 1. Mosquito species collected along the Nhamundá and Abacaxis Rivers, Amazonas, Brazil.

Taxa	Number [a]	River		Sex [b]	Method of Capture [c]						
		Nhamundá	Abacaxis		CDC	CDC-UV	Shannon	Sweeping	Malaise	Suspended	Immature
Anophelinae											
Anopheles											
(*Anopheles*)											
eiseni Coquillett, 1902	1		1	F					X		
forattinii Wilkerson & Sallum, 1999	21	2	19	20F+Mgen	3	5	13				
mattogrossensis Lutz & Neiva, 1911	2		2	F		1	1				
peryassui Dyar & Knab, 1908	1		1	F			X				
shannoni Davis, 1931	5	1	4	F	2	1	2				
(*Anopheles*) sp.	7		7	F							
(*Nyssorhynchus*)											
goeldii Rozeboom & Gabaldon, 1941	1		1	Mgen		X					
konderi s.l.	7		7	F	4	3					
oswaldoi s.l.	26	2	24	F	5	19	2				
triannulatus (Neiva & Pinto, 1922)	2	1	1	Mgen+F	1			1			
goeldii / *dunhami* [d]	3	2	1	F							
konderi / *oswaldoi* [d]	1		1	Fdam							
(*Nyssorhynchus*) sec. *Albimanus*	1		1	Fdam							
(*Nyssorhynchus*) sp.	27		27	Fdam							
(*Stethomyia*)											
canorii Floch & Abonnenc, 1945	2		2	Mgen	1			1			
kompi Edwards, 1930	8	1	7	F	5	1	2				
nimbus (Theobald, 1902)	10	4	6	9MGen+F				7	2		1
thomasi Shannon, 1933	2		2	Mgen		X					
nimbus / *thomasi* [d]	33	15	18	F							
Anopheles sp.	6	2	4	4Fdam+2Mdam							
Total *Anopheles*	166	30	136								
Culicinae											
Aedeomyiini											
Aedeomyia											
(*Aedeomyia*)											
squamipennis (Lynch Arribalzaga, 1878)	6	1	5	F	5						1
Total *Aedeomyia*	6	1	5								
Aedini											
Haemagogus											
(*Haemagogus*)											
baresi Cerqueira, 1960	2		2	F				X			
janthinomys Dyar, 1921	1		1	Mgen				X			
Haemagogus sp.	1	1		Fdam							
Total *Haemagogus*	4	1	3								
Aedes											
(*Howardina*)											
arborealis Bonne-Wepster & Bonne, 1919	1		1	F				X			
fulvithorax (Lutz, 1904)	1	1		F					X		

Continues

Appendix 1. Continued.

Taxa	Number[a]	River		Sex[b]	Method of Capture[c]						
		Nhamundá	Abacaxis		CDC	CDC-UV	Shannon	Sweeping	Malaise	Suspended	Immature
(*Ochlerotatus*)											
fulvus (Wiedemann, 1828)	17	12	5	Mgen+16F	5	5	6	1			
oligopistus Dyar, 1918	1		1	F	X						
rhyacophilus (Costa Lima, 1933)	15	2	13	14F+Mgen	1	2		12			
scapularis (Rondani, 1848)	5	5		F		1	4				
serratus (Theobald, 1901)	5	2	3	3F+2Mgen	1	1		3			
near *pectinatus* F1[e]	3		3	Mgen	1			3			
near sG *Infirmatus* F1[e]	1	1		Mgen				X			
hastatus / oligopistus [d]	1	1		Fdam							
serratus / nubilus [d]	10	5	5	Fdam							
(*Ochlerotatus*) sG *Infirmatus*	25	16	9	F							
(*Ochlerotatus*) sp.	2		2	Fdam							
(*Protomacleaya*)											
argyrothorax Bonne-Wepster & Bonne, 1919	2		2	Mgen+F				X			
Aedes sp.	1		1	Fdam							
Total *Aedes*	90	45	45								
Psorophora											
(*Grabhamia*)											
dimidiata Cerqueira, 1943	3	3		F	1	1	1				
(*Janthinosoma*)											
albigenu (Peryassú, 1908)	35	3	32	F	9	4		21	1		
albipes (Theobald, 1907)	13	5	8	F	2	3	1	7			
amazonica Cerqueira, 1960	49	10	39	47F+2Mgen	8	10	1	30			
circumflava Cerqueira, 1943	1		1	F	X						
discrucians (Walker, 1856) [e]	2	2		Mgen				X			
ferox (Humboldt, 1819)	44	38	6	35Mgen+9F	1	1		38		4	
(*Psorophora*)											
ciliata (Fabricius, 1794)	1		1	F		X					
cilipes (Fabricius, 1805)	1	1		Mgen				X			
Psorophora sp.	29	9	20	28Fdam+Mdam							
Total *Psorophora*	178	71	107								
Culicini											
Culex											
(*Aedinus*)											
accelerans Root, 1927	2	1	1	F		1				1	
amazonensis (Lutz, 1905)	5	2	3	F	1	1		3			
guyanensis Clastrier, 1970	1		1	F				X			
clastrieri / guyanensis [d]	4	1	3	F							
(*Aedinus*) sp.	3		3	Fdam							
(*Anoedioporpa*)											
luteopleurus (Theobald, 1903) [e]	1	1		F						X	
originator Gordon & Evans, 1922	2	2		Mgen+F				X			
(*Anoedioporpa*) sp.	10	1	9	Fdam							

Continues

Appendix 1. Continued.

Taxa	Number [a]	River		Sex [b]	Method of Capture [c]						
		Nhamundá	Abacaxis		CDC	CDC-UV	Shannon	Sweeping	Malaise	Suspended	Immature
(*Carrollia*)											
urichii (Coquillett, 1906)	5	5		3F+2Mgen							X
urichii / anduzei [d]	2	2		F							
(*Carrollia*) sp.	1		1	Fdam							
(*Culex*)											
bidens Dyar, 1922	1	1		F			X				
chidesteri Dyar, 1921	2		2	F		X					
declarator Dyar & Knab, 1906	255	10	245	245F+Mgen	163	82	10				
dolosus Lynch Arribalzaga, 1891	1		1	F	X						
mollis Dyar & Knab, 1906	456	29	427	450F+6Mgen	275	165	10	4	1	1	
usquatissimus Dyar, 1922	1		1	Mgen				X			
coronator / *usquatus* [d]	36	19	17	F							
mollis / *declarator* [d]	3	3		Fdam							
(*Culex*) gr. *Coronator*	17		17	F							
(*Culex*) sp.	245	8	237	243Fdam+2Mdam							
(*Melanoconion*)											
adamesi Sirivanakarn & Galindo, 1980	2		2	F	X						
alogistus Dyar, 1918	3		3	Mgen	1	2					
bequaerti Dyar & Shannon, 1925	77	64	13	48F+29Mgen	10	52	13	2			
brachiatus Hutchings & Sallum, 2008 [f]	1		1	Mgen		X					
caudatus Clastrier, 1970	8		8	Mgen		5	3				
caudelli (Dyar & Knab, 1906)	24	22	2	Mgen	2	16	3	3			
clarki Evans, 1924	4		4	F		2	2				
comatus Sénevet & Abonnenc, 1939	1	1		Mgen		X					
coppenamensis Bonne-Wepster & Bonne, 1919	4		4	Mgen	1	3					
corentynensis Dyar, 1920	1		1	Mgen	X						
crybda Dyar, 1924	13		13	F	8	4	1				
dolichophyllus Clastrier, 1970	3	1	2	2F+Mgen	1	1	1				
eastor Dyar, 1920	4		4	Mgen	1	2	1				
eknomios Forattini & Sallum, 1992	481	2	479	468F+13 Mgen	309	154	4	14			
fairchildi Galindo & Blanton, 1954	9	3	6	Mgen	2	3	4				
foliafer Komp & Rozeboom, 1951	1	1		Mgen		X					
gnomatos Sallum, Hutchings & Ferreira, 1997	124		124	F	82	40	1		1		
innovator Evans, 1924	3	3		Mgen	1	1	1				
johnsoni Galindo & Mendez, 1961	24		24	19 Mgen+5F	9		15				
pedroi Sirivanakarn & Belkin, 1980	6	3	3	5F+ Mgen	2	3				1	
phyllados Hutchings & Sallum, 2008 [f, g]	15	5	10	Mgen	2	9	2	2			
pilosus (Dyar & Knab, 1906)	5	4	1	Mgen	1	1	1	1	1		
portesi Senevet & Abonnenc, 1941	3		3	F	X						
putumayensis Matherson, 1934	1	1		Mgen				X			
rooti Rozeboom, 1935 [e]	2	1	1	Mgen			1	1			
spissipes (Theobald, 1903)	91	4	87	88F+3Mgen	77	7	2	5			
symbletos Sallum & Hutchings, 2003	5	1	4	Mgen	1	2		2			

Continues

Appendix 1. Continued.

Taxa	Number [a]	River		Sex [b]	Method of Capture [c]						
		Nhamundá	Abacaxis		CDC	CDC-UV	Shannon	Sweeping	Malaise	Suspended	Immature
theobaldi Lutz, 1904	415	23	392	F	251	149	15				
trigeminatus Clastrier, 1970 [e]	1		1	Mgen		X					
vaxus Dyar, 1920	587	122	465	395F+192Mgen	208	221	108	45	2	3	
near *creole* F1	4	4		Mgen		X					
near *eastor* F1	5		5	Mgen	2	1		2			
near *silvai* F1 [e]	8	5	3	Mgen		4	1	2	1		
near *vaxus* F1	19	3	16	MgeN	3	6	8	2			
near *vaxus* F3	158	142	16	138F+20Mgen	24	56	24	52	2		
near *venezuelensis* F1[e]	2	2		Mgen				X			
(*Melanoconion*) sG *Bastagarius*	3		3	Mdam							
(*Melanoconion*) sG *Caudelli*	3	3		F							
(*Melanoconion*) sG *Distinguendus*	1		1	Mdam							
(*Melanoconion*) sG *Pilosus*	2	2		F							
(*Melanoconion*) gr. *Atratus*	9	1	8	F							
(*Melanoconion*) gr. *Educator*	34	15	19	33F+Mdam							
(*Melanoconion*) gr. *Pilosus*	61	12	49	57F+4Mdam							
(*Melanoconion*) gr. *Saramaccensis*	8		8	F							
(*Melanoconion*) sec. *Melanoconion*	119	3	116	F							
(*Melanoconion*) sec. *Spissipes*	2		2	F+Mdam							
(*Melanoconion*) sp.	1160	166	994	1124Fdam+36Mdam							
(*Microculex*)	1		1	Mgen							X
aureus Lane & Whitman, 1951 [e]	1		1	Mgen							X
(*Phenacomyia*)											
airozai Lane, 1945	67		67	66F+Mgen	40	27					
(*Phenacomyia*) sp.	3		3	Fdam							
(Subg. incerto)											
flochi Duret, 1969	11	8	3	9 Mgen+2F				8			3
Culex sp.	2		2	Fdam							
Total *Culex*	4653	712	3941								
Mansoniini											
Coquillettidia											
(*Rhynchotaenia*)											
arribalzagae (Theobald, 1903)	2	1	1	F		1			1		
lynchi (Shannon, 1931)	4	4		3F+M				1	3		
Coquillettidia sp.	1	1		F							
Total *Coquillettidia*	7	6	1								
Mansonia											
(*Mansonia*) sp.	1		1	F							
Total *Mansonia*	1	0	1								
Tribe Orthopodomyiini											
Orthopodomyia											
fascipes (Coquillett, 1905)	4		4	3F+Mgen	X						
Orthopodomyia sp.	1	1		Mdam							
Total *Orthopodomyia*	5	1	4								

Continues

Appendix 1. Continued.

Taxa	Number [a]	River		Sex [b]	Method of Capture [c]						
		Nhamundá	Abacaxis		CDC	CDC-UV	Shannon	Sweeping	Malaise	Suspended	Immature
Limatus											
durhami Theobald, 1901	1	1		F				X			
flavisetosus De Oliveira Castro, 1935	1		1	F				X			
pseudomethysticus (Bonne-Wepster & Bonne, 1919)	4	2	2	F				1	2	1	
Limatus sp.	3	3		Fdam							
Total Limatus	9	6	3								
Onirion											
brucei (Del Ponte & Cerqueira, 1938) [e]	1	1									X
Total *Onirion*	1	1	0								
Sabethes											
(*Sabethes*)											
amazonicus Gordon & Evans, 1922	2	1	1	F				X			
cyaneus (Fabricius, 1805)	1	1		F						X	
spixi Cerqueira, 1961	4	2	2	3F+M				2	2		
(*Sabethoides*)											
glaucodaemon (Dyar & Shannon, 1925)	4	2	2	F						X	
tridentatus Cerqueira, 1961	3	2	1	F						X	
(*Sabethoides*) sp.	5	2	3	4F+Mgen							
Sabethes sp.	2	1	1	Fdam							
Total *Sabethes*	21	11	10								
Trichoprosopon											
digitatum (Rondani, 1848)	8	2	6	5F+3Mgen		1		2	4	1	
Trichoprosopon sp.	1		1	Fdam							
Total *Trichoprosopon*	9	2	7								
Wyeomyia											
(Cruzmyia)											
kummi Lane & Cerqueira, 1942	1	1		F				X			
(*Dendromyia*)											
testei Senevet & Abonnenc, 1939	2	2		Mgen+F							X
ypsipola Dyar, 1922	1	1		F			X				
(*Dodecamyia*)											
aphobema Dyar, 1918	3	3		Mgen				1			2
(*Exallomyia*)											
tarsata Lane & Cerqueira, 1942	7	6	1	6F+M				2	4	1	
(*Hystatomyia*)											
near *baltae* F1 [e]	2	2		Mgen						1	1
(*Hystatomyia*) sp.	2	1	1	Mgen+F							
(*Phoniomyia*)											
splendida (Bonne-Wepster & Bonne, 1919)	1	1		Mgen						X	
(*Phoniomyia*) sp.	1	1		F							
(*Spilonympha*)											
aningae Motta & Lourenço, 2005 [e]	1	1		F				X			

Continues

Appendix 1. Continued.

Taxa	Number [a]	River		Sex [b]	Method of Capture [c]						
		Nhamundá	Abacaxis		CDC	CDC-UV	Shannon	Sweeping	Malaise	Suspended	Immature
(Subg. incerto)											
aporonoma Dyar & Knab, 1906	5	4	1	F				3		2	
argenteorostris Bonne-Wepster & Bonne, 1919	2	1	1	F					X		
flui Bonne-Wepster & Bonne, 1919	2	1	1	Mgen				1		1	
surinamensis Bruijning, 1959 [e]	1	1		Mgen					X		
prox. *moerbista*	2	2		F				1	1		
gr. *Flui*	1	1		Mgen							
Wyeomyia sp.	8	5	3	7F+M							
Total *Wyeomyia*	42	34	8								
Uranotaeniini											
Uranotaenia											
(*Uranotaenia*)											
apicalis Theobald, 1903	5	4	1	F	1	4					
ditaenionota Prado, 1931	1		1	F		X					
geometrica Theobald, 1901	4		4	F	1	3					
lowii Theobald, 1901	3		3	F		X					
pallidoventer Theobald, 1903	1	1		F		X					
pulcherrima Lynch Arribalzaga, 1891	18	1	17	12F+6M	2	14	1			1	
(*Uranotaenia*) sp.	5		5	Fdam							
Total *Uranotaenia*	37	6	31								
Toxorhynchitinae											
Toxorhynchitini											
Toxorhynchites											
(*Lynchiella*)											
haemorrhoidalis (Fabricius, 1787)	1		1	F						X	
Toxorhynchites sp.	1	1		Mgen							
Total *Toxorhynchites*	2	1	1								
Number of mosquitoes identified	5231	928	4303	4610F+621M							
Specimens not identified [h]	59	5	54								
Total number of specimens	5290	933	4357								

[a] Indicates the total number of specimens for each taxon.

[b] Indicates the sex and/or condition of the specimens collected: M = male; F = female; dam = damaged specimen; gen = identified using genitalia dissection.

[c] X = specimens of the taxon were only captured using this method.

[d] It was not possible to identify these specimens to species level because either there are no known characters which can be used to separate the females of these two species, or the characters used to separate these species are damaged.

[e] First published record for the state of Amazonas.

[f] First geographical range extension for this species since it was described (Hutchings & Sallum 2008).

[g] Includes a paratype of this species ((Hutchings & Sallum 2008).

[h] Includes either immature specimens which died during the rearing process or adult specimens which were damaged during the mounting process.

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