Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(5): 322-329

Received: 04-07-2019
Accepted: 06-08-2019

Mamadou Traoré
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire

Allassane F Ouattara
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire
Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, Unité de Contrôle Des Vecteurs, 01 BP 1303 Abidjan 01, Côte d'Ivoire

Drissa Coulibaly
Université Péléforo Gon Coulibaly de Korhogo, Biology and Animal Cytology Laboratory, Natural Sciences, BP 1328 Korhogo, Côte d'Ivoire

Constant GN Gbalégba
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire
Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, Unité de Contrôle Des Vecteurs, 01 BP 1303 Abidjan 01, Côte d'Ivoire

Donatié S Touré
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire

Koffi E Kwadjo
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire

Kouadio D Kra
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire

Mamadou Doumbia
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire

Correspondence
Mamadou Traoré
Biology and Animal Cytology laboratory, Natural Sciences, Nangui Abrogoua University, 02 BP 801 Abidjan 02 Côte d'Ivoire

Assessment of the risk of mosquitoes nuisance and appearance of vector-borne diseases in rubber production areas in Southern Côte d'Ivoire

Mamadou Traoré, Allassane F Ouattara, Drissa Coulibaly, Constant GN Gbalégba, Donatié S Touré, Koffi E Kwadjo, Kouadio D Kra and Mamadou Doumbia

Abstract
This study was conducted from November 2015 to October 2016 for larval collection and from December 2016 to September 2017 for adult collection, in two rubber producing localities (Bongo and Toupah) in southern Côte d'Ivoire. Overall, 39360 larvae of Culicidae was collected. After larval breeding, 28,364 adults were obtained containing six genus and 34 species. The most prevalent species in both areas were *Aedes aegypti, Ae. africanus, Culex quinquefasciatus, Cx. nebulosus* and *Anopheles gambiae*. Abundance of mosquitos larvae in Toupah (85.3%) and Bongo (80.2%) was higher in the rainy season comparing to the dry season. CDC light trap collected 4520 adult belonging to 5 genus and 16 species. From the 5 genus, *Culex* (62.6%) and *Mansonia* (32.4%) accounted for more than 95% of all mosquitoes collected. The high specific richness (16 species) and the high abundance (57,3% of specimens) of Culicidae were observed in Toupah area compared to Bongo area. Indeed, the abundance and diversity of Culicidae fauna are a serious epidemiological concern to the inhabitants of the study areas. Therefore, the effectiveness of bed net used are strongly recommended in order to reduce human and vector population contact and also the reduction of the prevalence of mosquito-borne diseases.

Keywords: Vector-borne diseases, risk of nuisance, seasonal abundance, mosquito, rubber production, CDC Light trap, Côte d'Ivoire

1. Introduction

Mosquitoes are prompt to colonize any collection of water on a solid substrate around the world. The colonization process is either temporary or permanent into cottages, polluted, clean, large, or small water collection, or border of wide rivers [1]. The expanding and emergence of vector-borne disease are generally associated with a deep environmental change resulting from high deforestation due to increased agricultural pressures [2]. In forest areas, Culicidae populations are affected by changes made by man for his existential needs [3]. Agricultural practices could, therefore, represent a permanent risk of arbovirus transmission [4]. The expansion of industrial plantations is a major cause, and yet, the ever-increasing and diversified needs of man continue to negatively impact and modify this natural environment [5]. Among other things, unsuitable methods of land use lead to the loss of habitats resulting in the disappearance of many animals including insects. This also affects the abundance and distribution of insects, particularly mosquitoes, vectors of many tropical diseases [2]. Moreover, the studies have shown that monoculture would promote the emergence of invasive species, biodiversity loss, and water and soil pollution [6]. In addition, studies of Boyer in 2006, have shown that monoculture would promote the emergence of invasive species, biodiversity loss, and water and soil pollution. Human-induced changes reflect the magnitude of the increase in the global average temperature. As mosquitoes are insects, this would affect the distribution of Culicidae species and therefore the balance of the ecosystem [7]. The diversity of inter and intraspecific behavior's is greatly influenced by climate, geographical and human action. Indeed, this determines the level of human-vector contact, as well as the different epidemiological facies of malaria [8]. In the same way, climate change induced by greenhouse gases and changes in land use will have a significant impact on the distribution and spread of these tropical disease vectors by 2050 [9]. In fact, the global average temperature will increase from 1.11 °C to 6.4 °C, and given the magnitude of this increase, ecosystems and species distribution may be subject to more significant changes [9]. In forest areas, Culicidae populations are affected by man-made changes for living purpose [3]. Therefore, Agricultural practices could, represent a potential risk of arbovirus transmission [4]. The main cause is the expansion of industrial plantations. The ever-increasing and diversified needs of man continue to modify the natural environment [5]. Moreover, monocultures were probably involved in water and soil pollution [6].

The diversity of inter and intraspecific behavior's is greatly influenced by climate, geographical and human action. Indeed, this determines the level of human-vector contact, as well as the different epidemiological facies of some diseases as malaria [7, 8]. In the same way, climate change induced by greenhouse gases and changes in land use will have a significant impact on the distribution and spread of these tropical disease vectors by 2050 [9]. As stated, the global average temperature will increase from 1.11 °C to 6.4 °C, with more significant changes onto ecosystems and species distribution [9].

Côte d'Ivoire is the first African country of rubber producer and ranks seventh in the world [10]. The Country production was 600,000 tons in 2017 and is expected to reach 850,000 tons in 2020, despite the sharp drop in rubber prices in the country in latest years. This Boom of rubber production is linked to the rapid expansion of rubber plantations due to poorly controlled deforestation [10]. The transformation of the environment through deforestation creates suitable habitats for rapid development of mosquitoes involved in diseases transmission which area public health problem. Mosquitoes from Culicidae family are the most important vectors involve in various viral and protozoan pathogens transmission that affect human and animal well-being [11]. Mature rubber plantations are ideal breeding sites for mosquitoes that transmit malaria, yellow fever, dengue and lymphatic filariasis in Côte d'Ivoire. The risk of exposure of rubber plantation workers to vectors bites would be significant given the time spent in farms, and the hand work often painful with a weak quality of personal protective equipment available for workers. In June 2002, during an outbreak of hemorrhagic fever in an Indian province, investigations concluded that latex collection cups were responsible for the multiplication of mosquitoes of *Aedes* genera, vector of dengue fever and yellow fever [12]. The risk of mosquito proliferation linked to the development of rubber tree cultivation in Côte d'Ivoire is worrying the scientific world and the policy makers on the resurgence of these dangerous pathologies. It is in this context that this study was conducted in two areas of high rubber production whose overall objective is to show the potential impact of rubber cultivation on the distribution of Culicidae fauna and assess the risk of nuisance and appearance of vector-borne diseases in rubber production areas. Specifically, to study the diversity and abundance of larvae fauna and adult mosquitoes, and to assess and compare the

specific mosquito composition in the different study sites according to seasons.

The transformation of the environment through deforestation creates suitable habitat for mosquitoes

2. Materials and Methods

2.1. Study areas

The study was carried out in Bongo and Toupah, two areas of intensive rubber cultivation in Côte d'Ivoire (Fig. 1). Bongo (5°30'29.09"N; 3°32'51.32"W) is located in the department of Grand-Bassam (South-East of Côte d'Ivoire) and Toupah (5°22'15.37"N; 4°35'47.11"W) is located in the department of Dabou (South of Ivory Coast). The two localities have rubber plantation owned by SAPH (Société Africaine de Plantation d'Hévéa). The study areas have humid tropical climate with two rainy seasons (Long rainy season: December March; short rainy season: October and November) and two dry seasons (long dry season: December- March, short dry season: June, August and September). The average of annual rainfall is around 1 500 mm and the temperature range in 25 °C and 26 °C. Both study areas have facilities that include primary schools, sports ground and a rural health center.

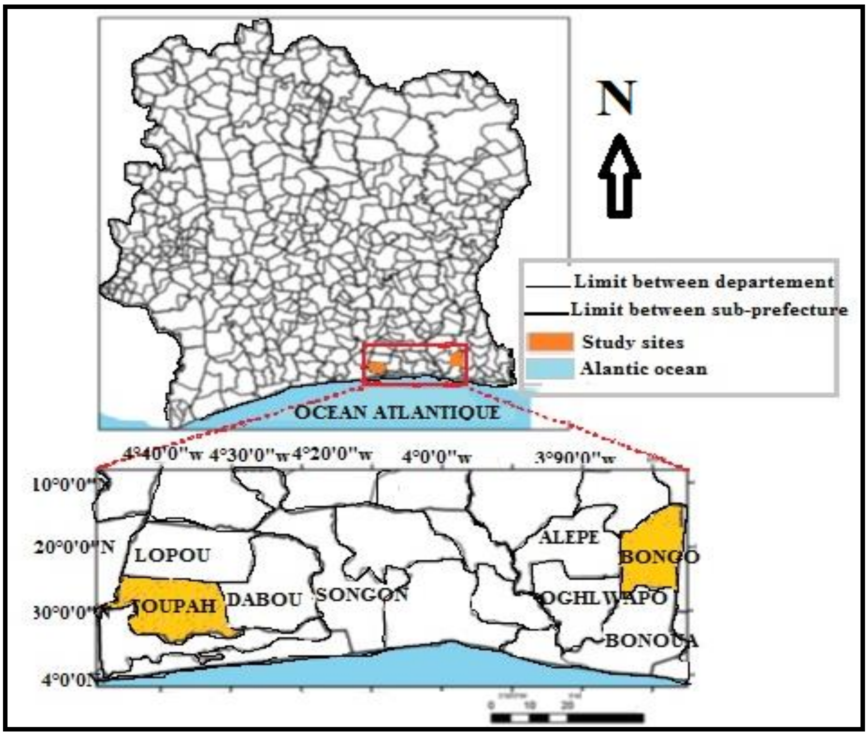


Fig 1: Location of study areas in Côte d'Ivoire.

2.2. Study design and site selection

The study was conducted in three different sites (habitations, mature rubber area and primary forest area) from each study area. Larvae and adults were collected monthly with independent collection methods applied on sites. Every month, collections were made simultaneously in each site.

2.3. Larvae collection

Larvae were collected monthly using the "Dipping" method [13]. Larvae collected were stored in plastic containers and transported from fields to the entomology laboratory of University Nangui Abrogoua for rearing. Larvae were fed with cat food. Adult mosquitoes from wild larvae were identified morphologically using identification key [13].

2.4. Adult collection

Adult mosquitoes were collected monthly through light traps method (Fig. 2). Each CDC light trap was associated with a CO_2 odor source in order to collected various mosquitoes as mentioned elsewhere [14-17]**.** This trapping method is consistent for arbovirus research in tropical countries. Fifteen light-traps were used in each habitat type. In habitations sites, eight (8) CDC light trap were put inside and seven (7) outside the house. Every month mosquitoes were collected from the traps in the morning on to a week from December 2016 to August 2017. In selected houses, traps were hung near an occupied bed covered with either an untreated or treated net, approximately at 1.5 m from the floor surface and placed at the end where the occupant's feet lay according to the protocol of Mboera [18]. In both study areas, there were 90 light traps.

Fig 2: CDC Light trap in rubber plantation **1:** CDC Light trap 2: Carbon source

3. Results

3.1. Diversity of larvae fauna from Culicidae

During the study, 2364 pupae and 36,996 larvae of mosquitoes were collected with 46.6% in Toupah and 53.4% in Bongo, including 15,278 (41.3%) larvae of *Aedes*, 13,421 (36.3%) larvae of *Culex*, 5524 (14.9%) larvae of *Anopheles* and 2773 (7.5%) for other larvae species. In Toupah, artificial breeding sites were more productive with 10,846 (65.2%) offprings against 6433 (37.2%) for natural breeding sites. Similarly, in Bongo area, artificial larval habitats were more productive (n = 13,749; 70.7%) compared to natural habitats (n = 5968; 30.8%). In both areas, *Aedes* (n =15,278) was the most abundant genus followed by *Culex* (n =13,421) and *Anopheles* (n = 5524) (Table 1). Regarding the typology of artificial larval habitats in Toupah, rubber collection containers were the most productive (53.7%) and streams identify as natural larval habitats were productive (11.7%) as well. In Bongo area, rubber collection containers were more productive (44.5%) than puddles (13.6%) (Table 2). Table 3 show the species compositions from wild larvae rearing. Overall, the emergence rate was 71.7%. In both study areas, the emergence rate is higher for Aedes genus (45.9% in Toupah and 44.2% in Bongo) with *Aedes aegypti* the most observed species in both areas (Table 3).

Table 1: Distribution of mosquitoes genus according to Larval habitats in Toupah

Genus	Toupah				
	Anopheles n (%)	**Aedes n (%)**	**Culex n (%)**	**Others n (%)**	**Total (%)**
Natural breeding sites					
Lagoon	0 (0.0)	0 (0.0)	1827(33.7)	85 (6.4)	1912 (5.3)
Temporary pond	0 (0.0)	82 (1.1)	88 (1.6)	18 (1.3)	188 (1.1)
Shallow	851 (32.3)	127 (1.7)	100 (1.8)	70 (5.2)	1148 (6.6)
Tree /stone cavity	0 (0.0)	50 (0.7)	29 (0.5)	13 (1.0)	92 (0.5)
Stream	623 (23.6)	54 (0.7)	1087 (19.2)	261 (19.4)	2025 (11.7)
Puddle	0 (0.0)	564 (7.4)	244 (4.3)	260 (19.4)	1068 (6.2)
Sub-total 1	1474 (55.9)	877 (11.5)	3375 (59.5)	707 (52.7)	6433 (37.2)
Artificial breeding sites					
Tyre	131 (5.0)	510 (6.8)	140 (2.5)	58 (4,32)	839 (5.0)
Container	905 (34.3)	6236 (82.7)	1295 (22.8)	515 (38,4)	8951 (53.7)

Septic tank	128 (4.9)	0 (0.0)	866 (15.3)	62 (4.6)	1056 (6.4)
Sub-total 2	1164 (44.1)	6746 (88.5)	2301 (40.5)	635 (5.9)	10846 (62.8)
Total (%)	2638 (100)	7623 (100)	5676 (100)	1342 (100)	17279 (100)
n= number of specimen					

Table 2: Distribution of mosquitoes genus according to Larval habitats in Bongo

	Bongo				
Genus	**Anopheles n (%)**	**Aedes n (%)**	**Culex n (%)**	**Others n (%)**	**Total (%)**
Natural breeding sites					
Footprint	325 (11.3)	0 (0.0)	320 (4.1)	335 (23.4)	980 (5.0)
Tree /stone cavity	0 (0.0)	21 (0.3)	0 (0.0)	4 (0.3)	25 (0.1)
Stream	876 (30.4)	83 (1.1)	1065 (13.8)	314 (21.9)	2338 (12.1)
Puddle	845 (29.3)	599 (7.8)	926 (12.0)	255 (17.8)	2625 (13.6)
Sub-total 1	2046 (70.9)	703 (9.2)	2311 (29.8)	908 (63.5)	5968 (30.3)
Artificial breeding sites					
Used tyre	353 (12.2)	770 (10.1)	138 (1.8)	85 (5.9)	1346 (6.9)
Used container	487 (16.9)	6182 (80.8)	1692 (21.8)	297 (20.8)	8658 (44.5)
Domestic waste water	0 (0.0)	0 (0.0)	1251 (16.2)	116 (8.1)	1367 (7.0)
Septic tank	0 (0.0)	0 (0.0)	1741 (22.5)	0 (0.0)	1741 (8.9)
Unused swimming pool	0 (0.0)	0 (0.0)	612 (7.9)	25 (1.7)	637 (3.3)
Sub-total 2	840 (29.1)	6952 (90.8)	5434 (70.2)	523 (36.5)	13749 (69.7)
Total (%)	2886 (100)	7655 (100)	7745 (100)	1431 (100)	19717 (100)
n=number of specimen					

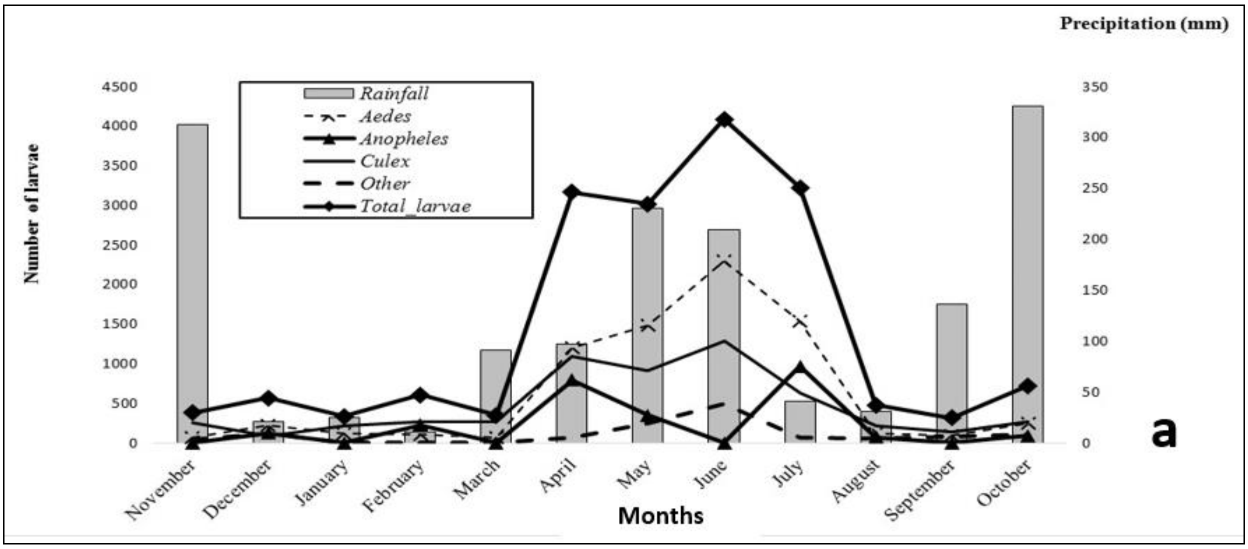
Table 3: Distribution of adult mosquito species after rearing

Aedes	**n**	**%**	**Culex**	**n**	**%**	**Anopheles**	**n**	**%**	**Others**	**n**	**%**	**Total**
Toupah												
Ae. aegypti	2931	22.3	*Cx. quinquefasciatus*	1558	11.9	*An. gambiae*	1103	8.4	*Toxo. brevipalpis*	415	3.2	
Ae. africanus	1340	10.2	*Cx. nebulosus*	912	6.9	*An. funestus*	57	0.4	*Eret. chrysogaster*	173	1.3	
Ae. luteocephalus	558	4.2	*Cx. decens*	927	7.1	*An. nili*	18	0.1	*Eret. quinquevitatus*	226	1.7	
Ae. tarsalis	256	1.9	*Cx. cinereus*	448	3.4				*Urano. fraseri*	90	0.7	
Ae. opok	187	1.4	*Cx. tigripes*	214	1.6				*Urano. balfouri*	146	1.1	
Ae. furcifer	199	1.5	*Cx. poicilipes*	126	1.0				*Urano. bilineata*	170	1.3	
Ae. argenteoventrilis	165	1.3	*Cx. perfiscus*	94	0.7							
Ae. hirsitus	122	0.9	*Cx. triffilatus*	120	0.9							
Ae. haworti	145	1.1	*Cx. ingrami*	113	0.9							
Ae. vittatus	111	0.8	*Cx. anntenatus*	123	0.9							
Ae. cozi	8	0.1	*Cx. annulioris*	40	0.3							
			Cx. grahami	37	0.3							
Total	6022	45.9	Total	4712	35.9	Total	1178	8.97	Total	1220	9.3	13132
Bongo												
Ae. aegypti	3598	23.6	*Cx. quinquefasciatus*	2085	13.7	*An. gambiae*	1476	9.7	*Eret. chrysogaster*	337	2.2	
Ae. africanus	2027	13.3	*Cx. nebulosus*	1422	9.3	*An. funestus*	215	1.4	*Eret. quinquevitatus*	257	1.7	
Ae. luteocephalus	318	2.1	*Cx. cinereus*	1121	7.4				*Toxo. brevipalpis*	223	1.5	
Ae. opok	196	1.3	*Cx. decens*	568	3.7				*Urano. bilineata*	141	0.9	
Ae. tarsalis	146	1.0	*Cx. annulioris*	243	1.6				*Eret. inornatus*	87	0.6	
Ae. vittatus	124	0.8	*Cx. tigripes*	253	1.7							
Ae. hirsitus	140	0.9	*Cx. anntenatus*	61	0.4							
Ae. haworti	109	0.7	*Cx. perfiscus*	5	0.0							
Ae. argenteoventrilis	78	0.5	*Cx. grahami*	2	0.0							
Total	6736	44.2	Total	5760	37.8	Total	1691	11.1	Total	1045	6.9	15 232

n= number of specimens

3.2. Seasonal variation of larvae abundance

Overall the highest number of larvae was collected in April, May, June and July representing the rainy season in the two sites with the pick observed in June (Fig.3). Larvae of *Aedes aegypti*, which are the most abundant, were more collected during the rainy season.



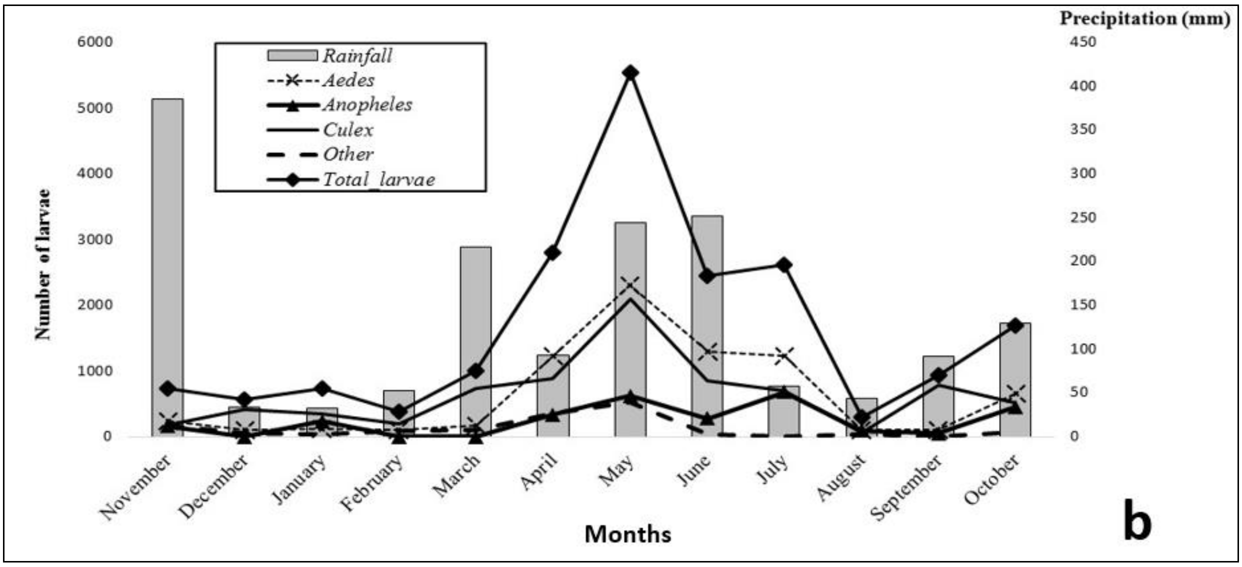


Fig 3: Larval abundance according to rainfall in Toupah (a) and Bongo (b) in 2015 and 2016. X-axis represent Months and y-axis represent number of larvae

3.3. Mosquitoes biting and feeding behaviour

Light traps collection allowed to collect 4520 adult female mosquitoes. In total, 57.3% (n = 2590) of mosquitoes were collected in Toupah against 42.7% (n=1930) in Bongo. On the 18 species, *Culex* was the most predominant genus with specific richness of 8. *Mansonia uniformis* was the most abundant species with 30.7% of identified species (Table 4). Furthermore, in forest and rubber collection sites, unfed and gravid mosquitoes were found. In Toupah, 74.6% of mosquitoes were caught around forest and 84.5% inside rubber plantation were either unfed or gravid. In Bongo, 88% of mosquitoes in forest and 93.5% in rubber plantation was unfed or gravid. However, in the village habitations, blood-fed mosquitoes (60.8% in Toupah and 50% in Bongo) were the most observed. More mosquitoes in these sites are endophagic behavior (Table 5).

Table 4: Specific composition of adult female mosquitoes collected by light traps in Toupah and Bongo.

Genus	Species	CDC-LTC		
		Toupah(n)	Bongo(n)	Total (%)
Anopheles	*An. nili*	86	0	86 (1.9)
	An. funestus	73	0	73 (1.6)
	An. gambiae	4	7	11 (0.2)
	An. pharaonsis	1	0	1 (0.1)
	Sub-total 1	164	7	171 (3.8)
Aedes	*Ae. aegypti*	11	4	15 (0.4)
	Ae. endrophilus	5	1	6 (0.1)
	Sub-total 2	16	5	21 (0.5)
Culex	*Cx. rima*	110	29	139 (3.1)
	Cx. decens	54	33	87 (1.9)
	Cx. tigripes	68	3	71 (1.6)
	Cx. cinerus	431	203	634 (14.0)
	Cx. annuloris	6	11	17 (0.4)

	Cx. nebulosus	816	474	1290 (28.5)
	Cx. quinquefasciatus	313	280	593 (13.1)
	Sub-total 3	1798	1033	2831 (62.6)
Mansonia	*Mn. africana*	15	64	79 (1.7)
	Mn. uniformis	582	806	1388 (30.7)
	Sub-total 4	597	870	1467 (32.4)
Coquilletidia	*cristata*	13	17	30 (0.7)
	Sub-total 5	13	17	30 (0.7)
	Total (%)	2588	1932	4520 (100)
CDC-LTC: center of diseases control-trap light catch				

Table 5: Distribution of mosquitoes collected by light traps according to their feeding status and habitat in Toupah and Bongo

Toupah																
	Forest					**Village (Inside, Outside)**					**Rubber field**					
Genus	**UM**	**BFM**	**HGM**	**GM**	**Sub-total 1**	**UM**	**BFM**	**HGM**	**GM**	**Sub-total 2**	**UM**	**BFM**	**HGM**	**GM**	**Sub-total 3**	**Total**
	(n)	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**	**(n)**
Anopheles	11	3	4	10	28	(7;1)	(31;2)	(5;1)	(3;2)	(46;6)	41	6	10	27	84	164
Aedes	2	0	0	1	3	(1;0)	(4;2)	(0;0)	(1;1)	(6;3)	2	0	1	1	4	16
Culex	201	97	32	118	448	(15;81)	(363;59)	(6;13)	(21;115)	(405;268)	304	34	40	299	677	1798
Mansonia	67	28	4	83	182	(5;37)	(67;22)	(2;13)	(25;2)	(99;74)	89	38	29	86	242	597
Coquilletidia	1	0	0	0	1	(0;0)	(0;3)	(0;0)	(0;0)	(0;3)	8	0	0	1	9	13
Total	282	128	40	212	662	(28;119)	(465;88)	(13;27)	(50;120)	(556;354)	444	78	80	414	1016	2588
Bongo																
	Forest					**Village (Inside, Outside)**					**Rubber field**					
Genus	**UM**	**BFM**	**HGM**	**GM**	**Sub-Total 1**	**UM**	**BFM**	**HGM**	**GM**	**Sub-Total 2**	**UM**	**BFM**	**HGM**	**GM**	**Sub-Total 3**	**Total**
Anopheles	2	0	0	0	2	(0;1)	(3;0)	(0;0)	(0;0)	(3;1)	1	0	0	0	1	7
Aedes	0	0	0	0	0	(0;0)	(3;0)	0	(1;0)	(4;0)	1	0	0	0	1	5
Culex	57	7	2	38	104	(11;55)	(234;100)	(10;26)	(159;119)	(414;300)	187	5	8	15	215	1033
Mansonia	21	8	1	14	44	(8;57)	(300;49)	(15;37)	(131;67)	(454;210)	116	2	10	34	162	870
Coquilletidia	0	0	0	0	0	(0;1)	(2;6)	(0;0)	(0;0)	(2;7)	8	0	0	0	8	17
Total	80	15	3	52	150	(19;114)	(542;155)	(25;63)	(291;186)	(877;518)	313	7	18	49	387	1932
n: number of specimen UM: unfed mosquito; BFM: blood fed mosquito; HGM: half-gravid mosquito; GM: Gravid mosquito																

4. Discussion

Identification of vector species and their relative abundance is important for a better understanding of zoonotic and human pathogens transmission and the epidemiology of emerging and re-emerging diseases [28]. The purpose of this study was to evaluate the level of involvement of industrial rubber plantations in the proliferation of mosquitoes which could potentially lead to a risk of recurrence of some diseases such as malaria, yellow fever and dengue fever. Larval collection has allowed to identify different type of mosquito breeding sites with relatively significant numbers. The highest number of larvae collected was recorded in Bongo. Breeding sites, especially those with at least one larva, have been found in the immediate environment of human populations, as reported in Mouila (Gabon) [23]. In both study areas, artificial breeding habitats were the most productive because people do not take care to eliminate the man-made water collection which could remain intact for several months. Among these artificial breeding sites, containers for food and for rubber collection, respectively in Toupah and Bongo were the most productive. That highlights the relationship between rubber production and mosquito rapid multiplication. In addition, these breeding sites are beneficial to the development of mosquitoes such as *Culex*, *Aedes* and *Anopheles*, involved in diseases spreading like malaria, chikungunya, filariasis, dengue, yellow fever and the zika virus [24]. In both study areas, the high number of *Aedes* larvae collected (41.3%) was due to the presence of several breeding sites potentially more favorable to the proliferation of this genus. Among *Aedes* larvae breeding sites, artificial breeding sites were the most productive. This finding is consistent with a study which compared the abundance of *Aedes* larvae in different areas where mosquitoes seemed to prefer anthropic breeding sites. [25]. The majority of breeding sites are man-made based on domestic and agricultural activities. Other findings from Côte d'Ivoire showed the responsibility of inhabitants in creating favorable conditions to the development and maintenance of mosquitoes through the creation of larval habitats [26]. In addition, the proximity of mosquito development sites to habitations could be a health risk and nuisance to surrounding human populations, as observed by several studies in Burkina Faso [27], Côte d'Ivoire [28] and Gainesville USA [29].

.The emergence rate of mosquito was higher for *Aedes* genus probably because of the high number of larvae due to eggs resistance to temperature and desiccation [26].

Significant relationships were found between abundance and seasonality, with an increase in mosquito abundance during the rainy season. The rainy season is a proper time for explosion of mosquito larvae due to water presence in breeding sites as observed in Gabon in 2018 [23], where mosquitoes abundance was probably related to the large number of permanent breeding sites during rainy season facilitating oviposition of mosquito species. The relatively high larval abundance indicates the existence of culicidae breeding sites due to the insufficiencies observed in the living and hygiene conditions of the inhabitants.

The findings seem to show that human activities are important factors leading mosquito production [29]. The presence of wastewater might explain the proliferation of *Culex*. Among *Culex* species collected, *Culex quinquefasciatus* was the most abundant. This could probably be explained by the presence of wide drainage systems congested with stagnant wastewater. This species preferred especially dirty water as observed in some study in Africa [30]. The low abundance of *Aedes* collected could be explained by the odor light traps, only used at night while *Aedes* have a diurnal bite activity (04pm - 06pm). However, whatever the quantity collected, Aedes should be considered as a potential risk in a context of outbreak of dengue and yellow fever, based on some cases identified in June-July 2019 in Abidjan.

Most of the unfed or gravid mosquitoes were collected in the forest and rubber plantations. In this types of habitats, warm-blooded animals are rare; limiting the ability of mosquitoes to have a proper blood meal. Probably, mosquitoes from rubber and forest sites feds on human and animals into habitations sites. All unfed and gravid mosquitoes collected seem to digest the blood meal in rubber and forest sites. However, some of the mosquitoes were found fed indoor human habitation

This study will not allow to identify the origin of the blood meal which represent a limitation. The description of the Culicidae fauna inside rubber plantation neighboring human habitation and forest is exhaustive because the collection tools was complementary.

5. Conclusion

Larval and adult collection revealed a high abundance of mosquitoes from several species in rubber plantations. Finding highlight the potential exposure risk to mosquitos nuisance and deadly diseases for populations living and working in such kind of agroecosystem. The destruction of potential larval sites and preventive measures such as sensitizing populations to a change in behavior must be popularized. More actions against adults mosquito should be done during the rainy season, in order to protect efficiently local populations and especially to rubber workers who spend long time in the rubber plantations.

6. Acknowledgements

The researchers would like to thank the SAPH company and the communities of Toupah and Bongo for their support and collaboration in the development of this work, as well as Mary Simwango (Zambia) for the valuable comments on the manuscript.

6. References

1. Mohrig W. Die Culiciden Deutschlands. Untersuchung zur Taxonomie, Biologie und Ökologie der einheimischen Stechmücken. Parasitologische Schriftenreihe. 1969; 18:1-260
2. Zahouli JBZ, Koudou GB, Müller P, Malone D, Tano Y, Utzinger J. Effect of land-use changes on the abundance, distribution, and host-seeking behavior of *Aedes* arbovirus vectors in oil palm-dominated landscapes, southeastern Côte d'Ivoire, PLoS ONE. 2017; 12(12):e0189082.
3. Pradel J, Rey D, Foussadier RBD. Étude écologique des moustiques (Diptera, culicidae) - vecteurs potentiels d'arboviroses dans la région rhone-alpes. Epidémiologie et santé animale. 2019; 51:81-94.
4. Yobo CM, Kacou CAMS, Adja MA, Ndille EE, Sagna AB, Coulibaly NG *et al*. Evaluation of Human Exposure to *Aedes* Bites in Rubber and Palm Cultivations Using an Immuno Epidemiological Biomarker. BioMed Research International, 2018, 9.
5. Assako ARJ. Apports des sciences sociales et de l'entomologie dans l'analyse de l'endémicité du paludisme à HEVECAM, une agro-industrie du Sud Cameroun. Géo-Eco-Trop. 2005; 29:101-114.
6. Boyer S, Calvez E, Chouin-Carneiro T, Diallo D, Failloux AB. An overview of mosquito vectors of Zika virus**.**, Microbes and Infection, 2018, https://doi.org/ 10.1016/j.micinf.01.006. 15 July 2019.
7. Zell R. Global climate change and the emergence/re-emergence of infectious diseases. International Journal of Medical Microbiology. 2004; 293(36):16-26.
8. Pages F, Orlandi-Pradinesb E, Corbelc V. Vecteurs du paludisme : biologie, diversité, contrôle et protection individuelle. Médecine et maladies infectieuses. 2006; 37:153-161.
9. Wuthichai K, Adisak B. Landscape Ecology and Epidemiology of Malaria Associated with Rubber Plantations in Thailand: Integrated Approaches to Malaria Ecotoping, Interdisciplinary Perspectives on Infectious Diseases. 2015, 17.
10. Anonymous. Rubber production in Côte d'Ivoire will triple to 2 Mt by 2023. Accessed 19/March/2019, from http://www.commodafrica.com/23-10-2018-irc-2018-la-production-de-caoutchouc-en-cote-divoire-triplera-dici-2023-2-mt.
11. Dutta PA, Bhattacharyya DR, Khan SA, Gogoi PR, Sharma CK. Mosquito biodiversity Prakash of Dibru-Saikhowa biosphere reserve in Assam. Indian Journal of Environmental. 2010b; 31(5):695-699.
12. Tangena AJA, Thammavong P, Wilson LA, Brey TP, Lindsay WS. Risk and Control of Mosquito-Borne Diseases in Southeast Asian Rubber Plantations. Trends in parasitology. 2016; 32(5):402-415.
13. Service M. Mosquito ecology: fields sampling methods. Applied science publishers, London, 1976, 583.
14. Reeves WC, Hammon W. Mosquitoes and Encephalitis in the Yakima Valley. Washington, IV. A trap for collecting live mosquitoes. The Journal of Infectious Diseases. 1942; 70(3):275-277.
15. Newhouse VF, Chamberla IRNW, Johnston JG, Sudia WD. Use of dry ice to increase mosquito catches of the C.D.C. Miniature Light Trap. Mosquito News, 1966; 26(l):30-35
16. Taylor DJ, Meadows KE, Baughma INE. Comparison of a chick-275-277, baited trap with the CDC miniature light trap. Mosquito News. 1966*;* 26:502-506.
17. Carestia RR, Savage LB. Effectiveness of Carbon Dioxide as a Mosquito Attractant in the C.D.C. Miniature Light Trap. Mosquito New. 1967*;* 27:90-92.
18. Mboera EGL, Kihonda J, Braks AHM, Knols GJB. Influence of centers for disease control light trap position, relative to a human-baited bed net, on catches of *Anopheles gambiae* and *Culex quinquefasciatus* in Tanzania. American Journal of Tropical Medicine and Hygiene. 1998; 59(4):595-596.
19. Gillies MT, De Meillon B. The Anophelinae of Africa South of the Sahara, II edn. Publication of the South Africa Institute of Medical Research 1968, 343.
20. Huang YM. A pictorial key for the identification of the subfamilies of Culicidae, genera of Culicinae, and subgenera of *Aedes* mosquitoes of the Afrotropical Region (Diptera: Culicidae). Proceedings of the Entomological Society of Washington. 2001; 103:1-53.
21. Rueda LM. Pictorial keys for the identification of mosquitoes (Diptera: Culicidae) associated with Dengue Virus Transmission. *Zootaxa*, 2004; 589:1-60.
22. Barbault R. Ecologie des peuplements : Structure,

dynamique et évolution. Paris, Masson Eds, 1992, 273.
23. Koumba AA, Christophe RZ, Koumba RM, Nguema LS, Djogbenou PO, Ondo GK *et al*. Distribution spatiale et saisonnière des gîtes larvaires des moustiques dans les espaces agricoles de la zone de Mouila, Gabon. International Journal of Biological and Chemical Sciences. 2018; 12 (4):1754-1769.
24. Merabti B. Identification, composition et structure des populations Culicidienne de la région de Biskra (Sud-est Algérien). Effets des facteurs écologiques sur l'abondance saisonnière. Essais de lutte Thèse de Doctorat. Dép Bio. Univ. Kasdi Merbah-Ouargla. 2015; 196.
25. Loncke S, Jacquet G, Barbazan P. Approche de la lutte contre les moustiques du genre Aedes par piégeage, 1992 ; Doc. Tech. 02/92/ITRM/DOC/ENT, 36p.
26. Tia E, Gbalégba NGC, M'bra KR, Kaba A, Boby OAM, Koné M *et al*. Etude du niveau de production larvaire d'*Anopheles gambiae* s.l. (Diptera : Culicidae) dans les différents types de gîtes à Oussou-yaokro au Centre-Ouest et à Korhogo, au Nord (Côte d'Ivoire). Journal of Applied Biosciences. 2016; 105:10170-10182.
27. Dambach P, Schleicher M, Korir P, Ouedraogo S, Dambach J, Sié A *et al*. Nightly biting cycles of Anopheles species in rural Northwestern Burkina Faso. Journal of Medical Entomology, J Med Entomol. 2018; 55(4):1027-1034.
28. Kone AB, Konan YL, Coulibaly ZI, Fofana D, Guindo-Coulibaly N, Diallo M *et al*. Évaluation entomologique du risque d'épidémie urbaine de fièvre jaune survenue en 2008 dans le district d'Abidjan, Côte d'Ivoire. Medecine et Sante Tropicales, 2013; 23:66-71.
29. Holderman CJ, Gezan SA, Stone AES CR, Connelly CR, Kaufman PE. Mosquitoes (Diptera: Culicidae) Collected From Residential Yards and Dog Kennels in Florida Using Two Aspirators, a Sweep Net, or a CDC Trap C. Journal of Medical Entomology. 2018; 55:230-236
30. Hougard JM, Mbentengam R, Lochouarn L, Escaffre H, Darriet F, Barbazan P *et al*. Lutte contre *Culex quinquefasciatus* par *Bacillus sphaericus*: résultats d'une campagne pilote dans une grande agglomération urbaine d'Afrique équatoriale Bulletin de l'Organisation mondiale de la Santé. 1993; 71(3, 4):367-375.