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SENEGAL 2019 FINAL ENTOMOLOGICAL MONITORING REPORT

JANUARY 1, 2019 – JANUARY 31, 2020

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CONTENTS

ACRONYMS

b/p/n	bites/person/night
CDC	Centers for Diseases Control and Prevention
CSI	Circumsporozoite Index
CSP	Circumsporozoite Protein
EIR	Entomological Inoculation Rate
ELISA	Enzyme-Linked Immuno-Sorbent Assay
HBR	Human Biting Rate
HLC	Human Landing Catches
ib/p/n	infected bites /person/night
IRD	Indoor Resting Density
IRM	Insecticide Resistance Monitoring
IRS	Indoor Residual Spraying
ITN	Insecticide-Treated Net
kdr	Knock Down Resistance
NMCP	National Malaria Control Program
PBO	Piperonyl Butoxide
Pf	*Plasmodium falciparum*
PMI	President's Malaria Initiative
PSC	Pyrethrum Spray Collection
UCAD	Université Cheikh Anta Diop
WHO	World Health Organization

EXECUTIVE SUMMARY

From January 2019 to December 2019, the President's Malaria Initiative (PMI) VectorLink Senegal Project conducted entomological monitoring activities in 24 selected sentinel districts located in the five geographical zones (Sahelian, Sudano-Sahelian, Sudanese, Sudano-Guinean, Sahelo-Sudanese zones) across the country. Vector surveillance activities including vector composition, density, behavior and entomological inoculation rate (EIR), were conducted every other month in 49 village sites (about two villages per sentinel district). Additionally, annual insecticide resistance monitoring was successfully conducted in 19 of the 24 districts. The susceptibility status of *An. gambiae* s.l. populations of each district was tested against pyrethroid, carbamate, organophosphate, pyrrole and neonicotinoid insecticides. Resistance intensity and synergist assays were conducted for pyrethroids.

Nine anopheline species were found across all sites during the monitoring period with *An. gambiae* s.l. representing the main malaria vector across all sites, followed by *An. funestus* s.l. Furthermore, molecular identification of *An. gambiae* s.l. collected by human landing catches (HLC) and pyretherum spray catch (PSC) revealed the presence of four species: *An. arabiensis, An. gambiae*, *An. coluzzii,* and *An. melas*. Overall, *An. arabiensis* was the most abundant species in the Sahelian, Sahelo-Sudanese, and Sudano-Sahelian zones while *An. gambiae* was predominant in the Sudanese and Sudano-Guinean zones. Few hybrids *An. coluzzii*/*An. gambiae,* were also identified in the Sudanese and Sudano-Guinean areas.

The biting rates of *An. gambiae* s.l. were higher during the rainy season, between September 2019 and October, with the highest rates recorded in the Sudanese area (27 bites/person/night (b/p/n) and the Sudano-Guinean area (25 b/p/n) and higher indoor biting (endophagic). *An. funestus* s.l. was generally less aggressive, with a maximum biting rate of 7 b/p/n, recorded in Ndoffane (Sudan-Sahelian zone). Furthermore, both vectors were more active between 02 a.m. and 05 a.m. during the night.

An. gambiae s.l. was more anthropophilic in the Sudanese and Sudano-Guinean zones compared to the other zones. In contrast, the anthropophilic rate was lower for *An. funestus* in the Sudano-Sahelian and Sudano-Guinean zones where horses and cows were the main sources of blood meals.

Both *An. gambiae* s.l. and *An. funestus* s.l. were found positive for *P. falciparum* circumsporozoitic protein with higher proportion recorded in the Sahelian zone. However, the average entomological inoculation rate (EIR) was higher in the Sudano-Guinean zone where higher biting rate was recorded.

Susceptibility of *An. gambiae* s.l. to pirimiphos-methyl was recorded in all sites, except in Diamniadio (Sudano-Guinean zone) and resistance to the three pyrethroids tested (deltamethrin, permethrin, and alpha-cypermethrin) was observed in all sites, except in Ndoffane where the colony was susceptible to deltamethrin. Susceptibility to bendiocarb was recorded in the Sudanese and Sudano-Sahelian zones, while possible resistance occurred in the Sahelian, Sahelo-Sudanese, and Sudano-Guinean zones. Susceptibility to clothianidin (13.2 mg/paper) and chlorfenapyr (200 µg/bottle) was recorded in all sites, except for chlorfenapyr in Kedougou.

A substantial increase in mortality of *An. gambiae* s.l. when pyrethroids were pre-exposed to piperonyl butoxide (PBO) as synergist – for deltamethrin mean mortality increased from 50.1% without PBO to 94.9% with PBO; for permethrin mean mortality increased from 50.8% without PBO to 86.6% with PBO.

The knock down resistance (*kdr*) mutations (west and east) were present within *An. arabiensis*, *An. gambiae* and *An. coluzzii*. The co-occurrence of the *kdr*-west and *kdr*-east mutations was recorded in all the other districts where they were both investigated, at a relatively lower frequency in the sentinel district of the Sudanese zone. No *kdr* east was detected in the Sahelian and Sahelo-Sudanese zones and the *kdr*-west mutation characterized

was at a frequency of 0.6 among the samples tested. Moreover, the prevalence of *kdr* mutations were higher in the Sudano-Guinean zone and particularly in the urban setting of Dakar, where all the specimens tested carried one or both mutations. The *Ace*-1^R mutation, was not detected in the majority of the sites except in Salementa and Saraya in the Sudano-Guinean zone were few resistance alleles were recorded.

The data collected will support the NMCP and the malaria vector control stakeholders (including PMI VectorLink) in the timing of indoor residual spraying (IRS) and in selecting and planning ITN distributions across the country.

I. INTRODUCTION

As part of an effort to scale up vector control interventions, the Senegal National Malaria Control Program (NMCP) received support from the U.S. President's Malaria Initiative (PMI) for entomological data collections and indoor residual spraying (IRS). In 2019, PMI VectorLink Senegal conducted longitudinal entomological monitoring activities including i) routine vector surveillance every two months in 24 sentinel districts sites spread across the different geographical zones of the country and ii) annual insecticide resistance monitoring in 19 of the 24 sentinel districts where vector surveillance was conducted. . The data collected aimed to support the NMCP and the malaria vector control stakeholders (including PMI VectorLink) in the timing of indoor residual spraying (IRS) programming and in planning the distribution of insecticide-treated nets (ITNs). Objectives of entomological surveillance are as follows:

- To determine vector species composition and distribution, and vector resting and biting behavior;
- To determine the susceptibility of the natural populations of *An. gambiae* s.l. to main insecticide molecules used in vector control interventions (ITNs and IRS);
- To determine the *Plasmodium falciparum* (*Pf*) infection rate among the populations of the two main malaria vectors (*An. gambiae* s.l. and *An. funestus* s.l.);
- To identify the blood meal sources and preferences of the females of the different vector species at the sentinel sites.

This report summarizes the results of the entomological surveillance carried out from January to December 2019.

2. METHODS

2.1 SENTINEL DISTRICTS AND SITES[1]

In 2019, entomological surveillance was carried in 24 sentinel districts (Figure 1) spread across five geographical zones (Sahelian, Sahelo-Sudanese, Sudano-Sahelian, Sudanese and Sudano-Guinean zones. Two sites were selected per district to conduct vector surveillance activities with one additional site in Tivaoune to equal 49 total village sites.

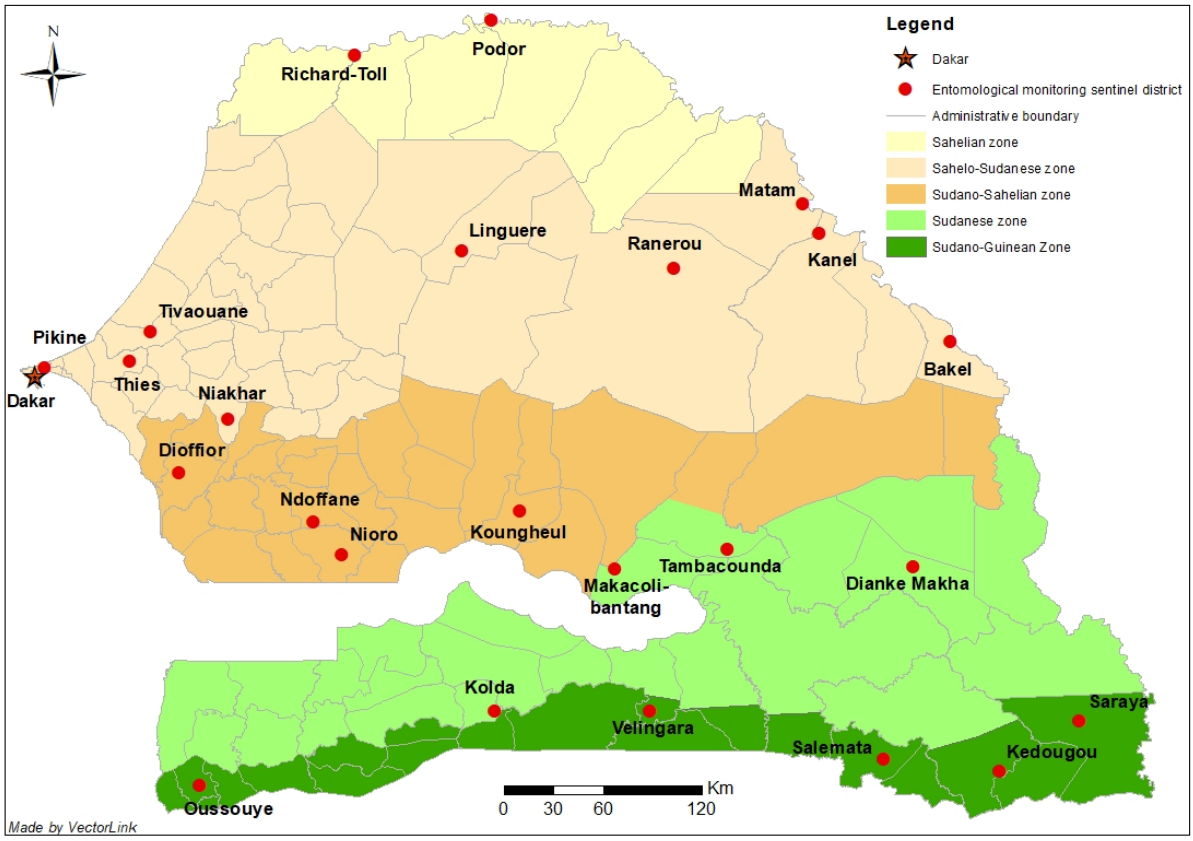
The Sahelian zone covers the dry area between Saint-Louis and the River Senegal in the Northern part of the country. Ongoing desertification is happening in the area where shrubs, some baobabs and acacias are mainly found. The Sahelo-Sudanese zone is spread from Dakar to Matam and from Louga to Djourbel with dry savannah, acacias, cheese trees, baobabs representing the main trees of the area. The Sudano-Sahelian area covers from Fatick/Kaolack to Tambacounda with denser savannah, forests with sparse baobabs, cheese trees, acacias and palm trees. The Sudanese zone represents the area from Tambacounda to Ziguinchor/Kolda with very dense savannahs and forests with cheese trees, baobabs, palm trees, and casuarinas. The Sudano-Guinean zone represents the South Casamance with humid tropical forest.

Nioro and Koungheul, located in the Sudano-Sahelian zone were former IRS sites. All the districts selected for monitoring were previously entomological monitoring districts except four of them: Salemata, Saraya, Kolda, and Makacoulibantang.

Additional entomological surveillance was conducted in Diourbel, Touba, and Kaolack as part of an urban landscape analysis. These results are presented as a separate report.

FIGURE 1: GEOGRAPHICAL LOCATION OF THE SENTINEL HEALTH DISTRICTS SURVEYED DURING THE 2019 ENTOMOLOGICAL SURVEILLANCE

[1]The 2020 PMI VectorLink Senegal IRS districts include Koungheul (Sudano-Sahelian zone), Koumpentoum and Maka Coulibanta (Sudanese zone) and Kedougou (Sudano-guinean zone) while the



The sentinel sites, entomological activities, and the frequency in each of the sentinel districts are described in the Table 1.

TABLE 1: SENTINEL DISTRICTS AND FREQUENCY OF THE ENTOMOLOGICAL SURVEILLANCE ACTIVITIES IN STUDIED VILLAGES

Sentinel District	Sentinel sites	Entomological activities	Frequency	IRS 2020 Districts*
Sahelian zone				
Richard Toll	Mbagame and Gankette Balla	**HLC**, **PSC** and **IRM**	Every two months	
Podor	Ndiayene-Pendao and Niandane	**HLC, PSC** and **IRM**		
Sahelo-Sudanese zone				
Matam	Sadel and Nabadji Ciwol	**HLC, PSC** and **IRM**	Every two months	IDB
Kanel	Haoure and Dembankane	**HLC, PSC** and **IRM**		IDB
Bakel	Gabou and Moudery	**HLC, PSC** and **IRM**		
Ranerou	Oudalaye and Fourdou	**HLC, PSC** and **IRM**		IDB
Linguere	Barkedji and Ouarkhokh	**HLC, PSC** and **IRM**		IDB
Tivaoune**	Diambalo, Ngadiaga, Thiaye, Touba Tawfekh	**HLC, PSC** and **IRM**		
Thies**	Beer	**PSC** and **IRM**		IDB
Pikine	Pikine	**PSC**		
Sudano-Sahelian zone				
Diofior	Palmarin FACAO, Simal	**HLC, PSC** and **IRM**	Every two months	

Niakhar	Kothiokh, Ngayokheme	**HLC, PSC** and **IRM**		
Koungheul≠	Ida Mouride, Pakala	**HLC, PSC** and **IRM**		PMI
Nioro≠	Ndrame Ndimb, Bamba Diakhatou, Camara	**HLC, PSC** and **IRM**		
Ndoffaneμ	Tawa Mboudaye, Sagnaneme	**HLC, PSC** and **IRM**		
	Sudanese zone			
Makacolibantang	Sinthiou Boure Banna Ndao, Ndoga Babacar	**HLC, PSC** and **IRM**	Every two months	PMI
Tambacounda	Wassadou, Badi	**HLC, PSC** and **IRM**		
Dianke Makha	Gouta, Soukouta	**HLC, PSC** and **IRM**		
Sudano-Guinean zone				
Kedougou	Tomboronkoto, Bandafassi	**HLC, PSC** and **IRM**	Every two months	PMI
Saraya	Bembou, MadinaDiankha	**HLC, PSC** and **IRM**		
Salemata	Diara Pont, Ethiolo	**HLC, PSC** and **IRM**		
Velingara	Medina Dianguette, Bonkonto	**HLC, PSC** and **IRM**		
Kolda	MissiraDemba, Sare Oggo	**HLC, PSC** and **IRM**		
Oussouye	Mlomp, Cadjinolle	**HLC, PSC** and **IRM**		

Note: HLC = human landing catches, PSC = pyrethroid spray collections and IRM = insecticide resistance monitoring
*: The districts of Tivaoune and Thies belong to the geographical area of Niayes for which five sentinel sites had been selected, four in Tivaoune and one in Thies.
** Islamic Development Bank (IDB) conducting IRS in 10 districts in 2020, of these VectorLink conducted entomological monitoring activities in five.
≠: Previous IRS districts
μ: Former external control of the previous IRS districts of Nioro

The annual refresher training was organized before the starting of any field activities, and all the field technicians and students involved in the monitoring were provided an overview of standard field and laboratory operational procedures and vector surveillance objectives.

2.2 VECTORS POPULATION DYNAMICS

Sampling of the vector populations was done by i) hourly human landing catches (HLCs) of host-seeking mosquito females inside and outside human dwellings, and ii) pyrethrum spray collections (PSCs) for indoor resting females (endophilic) in human habitations. The different collections were completed in accordance with the VectorLink Standard Operating Procedure 02/01 for HLC and Standard Operating Procedure 03/01 for PSC (all SOPs can be find here https://pmivectorlink.org/resources/tools-and-innovations/)

TABLE 2: ADULT MOSQUITOES COLLECTIONS

Collection Method	Time	Frequency	Sample*
PSC	7:00 am to 10:00 am	Once per site per collection time point	10 houses per site
HLC	8:00 pm to 6:00 am	Two consecutive nights per site per collection time point; indoors and outdoors	3 houses per site

* The same rooms and houses were maintained over the survey period.

In the field, the mosquitoes collected were sorted and *Anopheles* mosquitoes were morphologically identified using identification keys (Diagne *et al.,* 1994)), then counted. A sub-sample of female *Anopheles* vectors were ovary-dissected in the field to determine the parity rate. All collected females of *Anopheles* were stored individually in numbered Eppendorf tubes containing silica gel for subsequent laboratory analysis. Table 3 describes the entomological indicators calculated using the different collection methods.

TABLE 3: SUMMARY OF MALARIA ENTOMOLOGICAL INDICATORS PER COLLECTION METHOD

Collection Method	Indicator	Definition
HLC	Human biting rate (indoor and outdoor)	Mean number of bites / person / night
	Peak biting time	Hour with the highest human biting rate
	Parity rate	Percentage of parous mosquitoes
	Exophagic rate	Percentage of mosquitoes biting outside
	Endophagic rate	Percentage of mosquitoes biting inside
PSC	Indoor resting density	Mean number of mosquitoes / house / day
	% of fed females	Number of fed mosquitoes / total collected

2.3 WHO SUSCEPTIBILITY TEST

Susceptibility of adult *An. gambiae* s.l., the major malaria vector in Senegal, was assessed against different insecticides using the standard World Health Organization (WHO) susceptibility test kits, and CDC bottle assay procedures. Unfed adult females aged 3 to 5 days, reared from larvae collected from breeding sites within and around the sentinel sites, were used for the bioassays performed in each of the surveyed health districts. Diagnostic concentration of papers impregnated with three pyrethroids (deltamethrin 0.05%, permethrin 0.75%, alpha-cypermethrin 0.05%), an organophosphate (pirimiphos-methyl 0.25%), and a carbamate (bendiocarb 0.1%) were used to assess the susceptibility status *An. gambiae* s.l. populations at each site.

Insecticide susceptibility tests were completed following the WHO method (VectorLink Standard Operating Procedure 06/01), with the exception of tests with chlorfenapyr, which were performed using CDC bottle assays (VectorLink Standard Operating Procedure 04/01). Clothianidin (13.2 mg/paper) papers (neonicotinoid) were treated locally using the formulated product of SumiShield 50WG, 50% active ingredient, and a protocol designed by VectorLink. The susceptibility testing was conducted as described above and the mortality was recorded up to seven days post exposure.

When insecticide resistance of pyrethroids was confirmed, resistance intensity (high, moderate, and low) was also tested at five and ten times the diagnostic concentration of permethrin, deltamethrin, and alpha-cypermethrin using the WHO method (VectorLink Standard Operating Procedure 06/01).

Synergist assays with piperonyl butoxide (PBO 4%) were conducted for deltamethrin, permethrin, and alpha-cypermethrin according to the WHO tube test protocol (VectorLink Standard Operating Procedure 06/01) to determine the involvement of P450s in pyrethroid resistance.

Abbott's formula was used to correct the observed mortalities in the cases where the control mortality was above 5% and below 20%. The results were interpreted based on the WHO criteria (2013), as presented in Table 4.

TABLE 4: ANALYSIS AND INTERPRETATION OF INSECTICIDE SUSCEPTIBILITY DATA

Status	WHO threshold	Additional thresholds	Observations
Susceptible	98-100%	98-100%	Susceptibility confirmed
Resistant	< 98%	90-98%	Resistance suspected
		< 90%	Resistance confirmed

2.3.1 LABORATORY ANALYSIS

2.3.1.1 PLASMODIUM FALCIPARUM INFECTION RATE

The presence of *Pf* circumsporozoite protein (CSP) was characterized using the enzyme-linked immuno-sorbent assay (ELISA) method (Burkot et al., 1984; Wirtz et al., 1987) to determine the infection rates among host-seeking females. The sporozoite rate was calculated as the proportion (in %) of females found with the CS protein out of the total analyzed. The entomological inoculation rate (EIR) was calculated by multiplying the human biting rate by the circumsporozoite index (CSI).

2.3.1.2. ORIGIN OF BLOOD MEALS

The origin of blood meals was identified using the direct ELISA method described by Beier et al. (1988) on blood-fed females collected by PSC. The anthropophilic rate was calculated as the proportion of human blood among the total blood meals determined. The same formula was applied to estimate the host preference for the alternative animal hosts. Each host identified in mixed blood meals was counted and included in the calculation of anthropophilic and zoophilic rates.

2.3.1.3. MOLECULAR IDENTIFICATION OF AN. GAMBIAE S.L. SPECIES AND CHARACTERIZATION OF TARGET SITE RESISTANCE GENES

Sub-samples of dead and alive specimens of *An. gambiae* s.l. from the susceptibility tests, and those collected by HLC and PSC, were identified to species level by polymerase chain reaction (PCR) (Wilkins et al., 2006). Moreover, the presence of both knock down resistance (*kdr)* (L1014F and L1014S) and the *Ace1* (G119S) target site mutations were screened among dead and alive specimens exposed to insecticides using the methods described by Huynh (2007) and Wilkins (2006), respectively, for the *kdr* and *Ace*1^{R} genes.

2.4 STATISTICAL ANALYSES

Homogeneity tests were performed to compare all the entomological parameters estimated for the two main vector species across their range of distribution, using the standard Chi-square or the exact Fisher tests where appropriate at the significance level of 0.05. The 95% confidence intervals were calculated for each *Pf* infection rate. Entomological inoculation rates were compared using logistic regression.

3. RESULTS

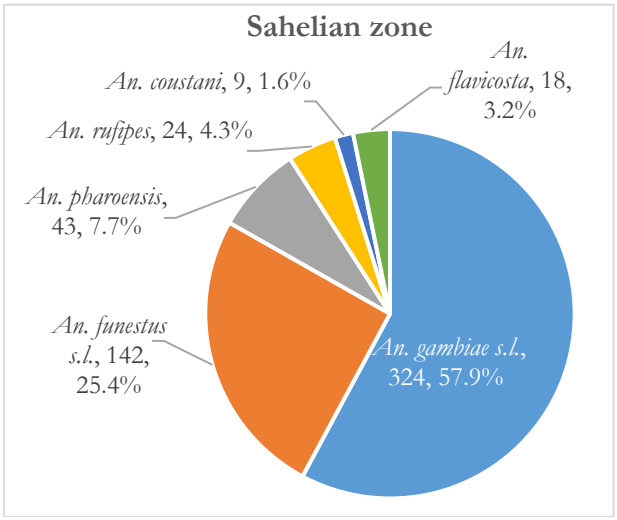
3.1 VECTOR POPULATION DYNAMICS

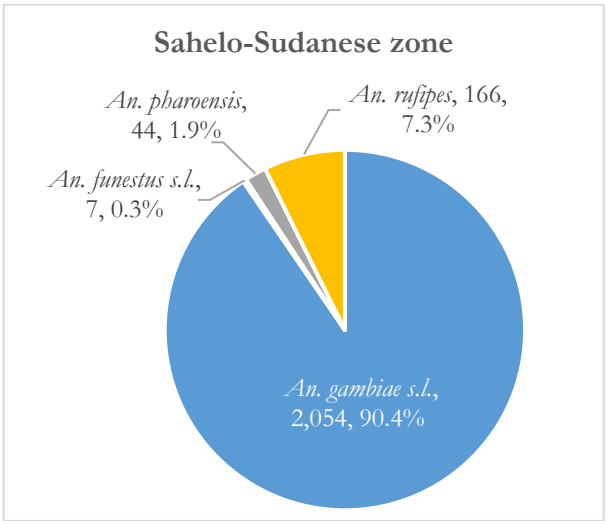
3.1.1 Species Composition

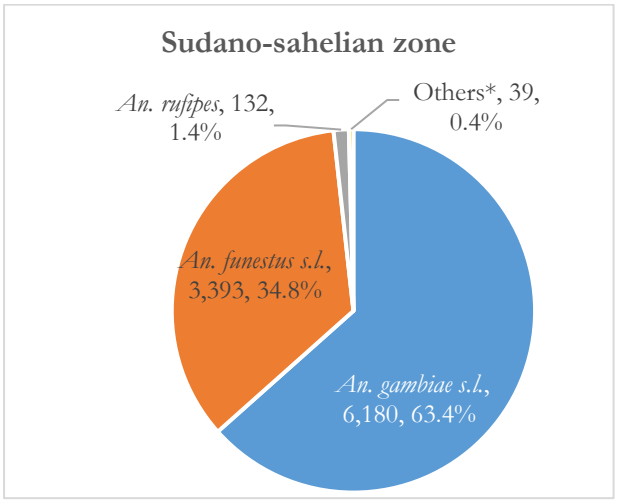
A total of 25,337 *Anopheles* mosquitoes were collected in all sentinel districts of all eco-geographical zones. The Sahelian zone recorded the lowest density with 2.2% (n=560) of the total *Anopheles* collected, followed by the Sahelo-Sudanese zone (8.9%, n=2,262), the Sudanese zone (16.9%, n=4,289), the Sudano-Guinean zone (33.7%, n=8,482), and the Sudano-Sahelian zone (38.5%, n=9,744). Overall, nine *Anopheles* species were collected during the monitoring (Table 5). Eight were found in the southern part of the country, with *An. squamosus* (Sudanese zone) and *An. nili* (Sudano-Guinean zone) found only in these areas. *An. gambiae* s.l., *An. funestus*, *An. pharoensis*, *An. rufipes,* and *An. coustani* were more widespread and present in almost all the surveyed eco-geographical areas. *An. flavicosta* was recorded only in the delta of the Senegal River (in the Sahelian zone), where six out of the nine anopheline species were found.

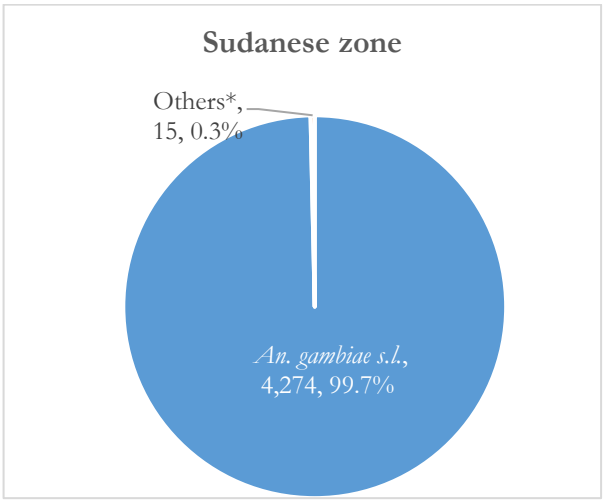
Overall, *An. gambiae* s.l. remained the predominant vector species in all areas (Figure 2). However, the proportions of *An. gambiae* s.l. were relatively low in the Sahelian (58%) and in the Sudano-Sahelian (63%) zones, where a higher number of *An. funestus* s.l. was recorded. *An. funestus* s.l. constituted the second most prevalent species in these two areas, particularly in Nioro and Ndoffane districts, both located in the Sudano-Sahelian (Annex A).

FIGURE 2. *ANOPHELES* SPECIES COMPOSITION BY GEOGRAPHICAL ZONE



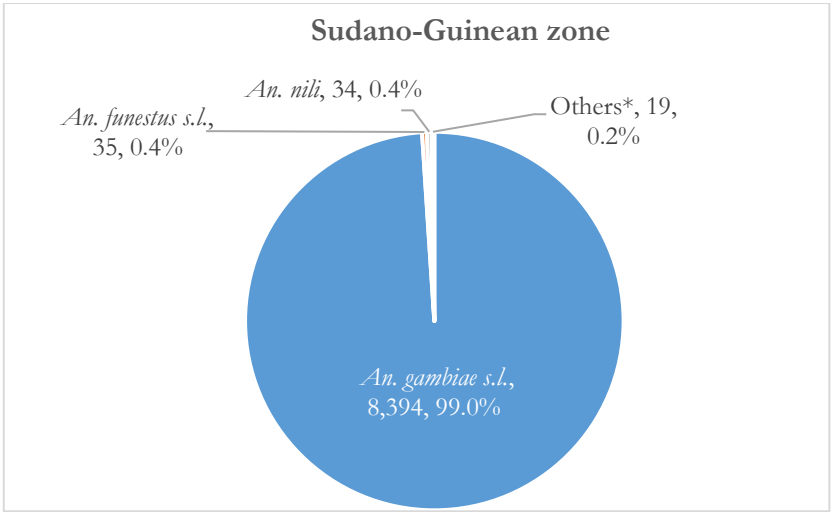






*Other species include *An. pharoensis* (29), *An. coustani* (5) and *An. welcomei* (5)

*Other species include *An. pharoensis* (2), *An. squamosus* (2), *An. rufipes* (3), *An. coustani* (7) and *An. nili* (1)



*Other species include *An. pharoensis* (12), *An. rufipes* (1), *An. coustani* (5) and *An. welcomei* (1)

3.1.2 *Anopheles gambiae* s.l. Human Biting Rate

3.1.2.1 Annual biting cycle of An. gambiae s.l.

The mean monthly peak human biting rates (HBR) were recorded between July and October, representing the period of rains in all the geographical zones (Figure 3). The Sudanese and Sudano-Guinean zone recorded the highest peaks with more than 50 b/p/n during the period. All the other months recorded very low density with less than 1b/p/n during most of the months. Additionally, *An. gambiae* s.l. hourly peak biting was recorded between 02 a.m. and 04 a.m. in all the geographical zones with the highest densities recorded in the Sudanese and the Sudano-Guinean zones (Figure 4)

The monthly results will help timing the implementation of any vector control measures and particularly IRS.

Figure 3: Monthly Variations of *An. gambiae* s.l. Human Biting Rate By geographical Area

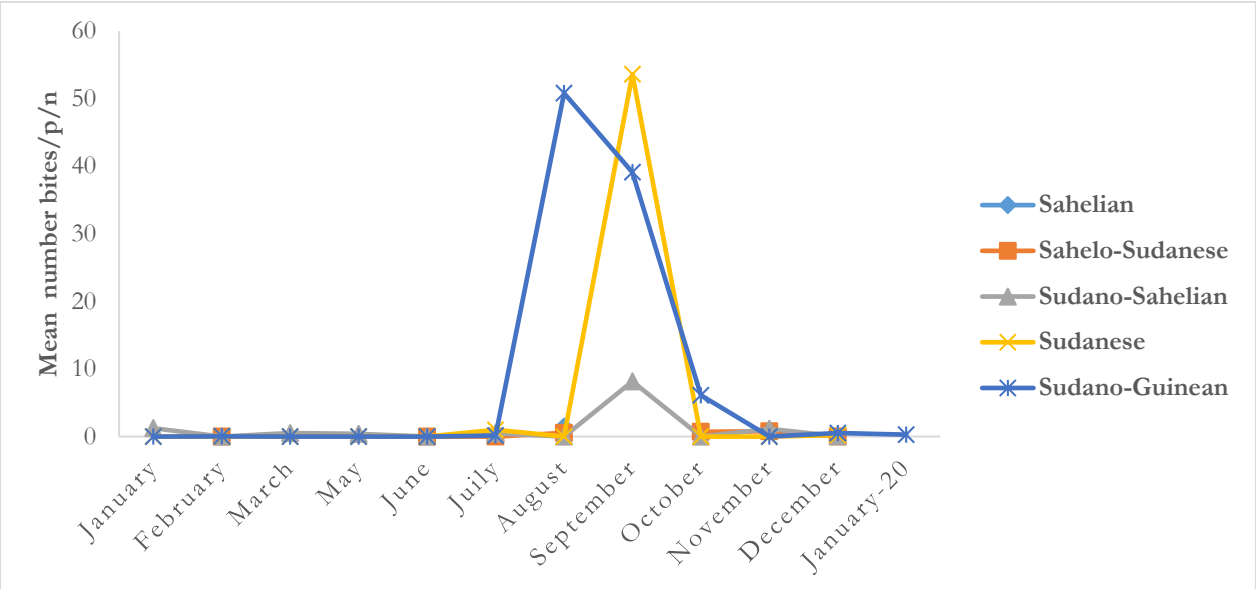
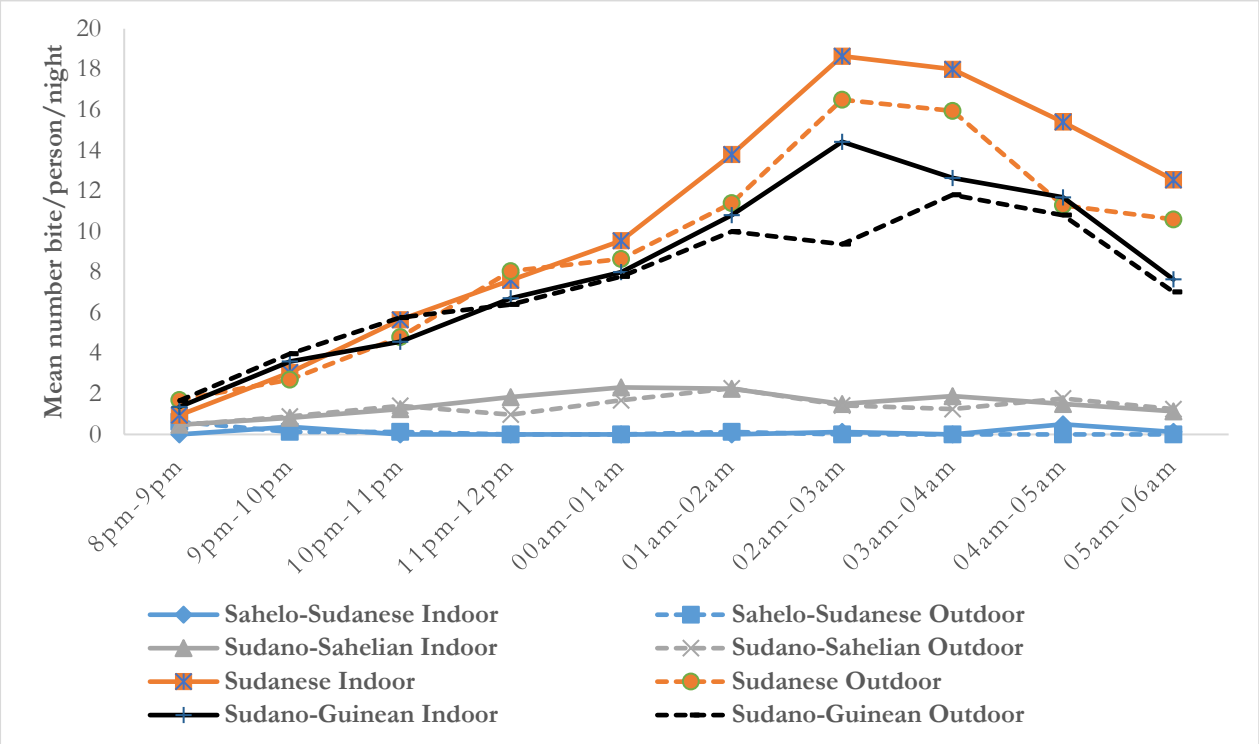


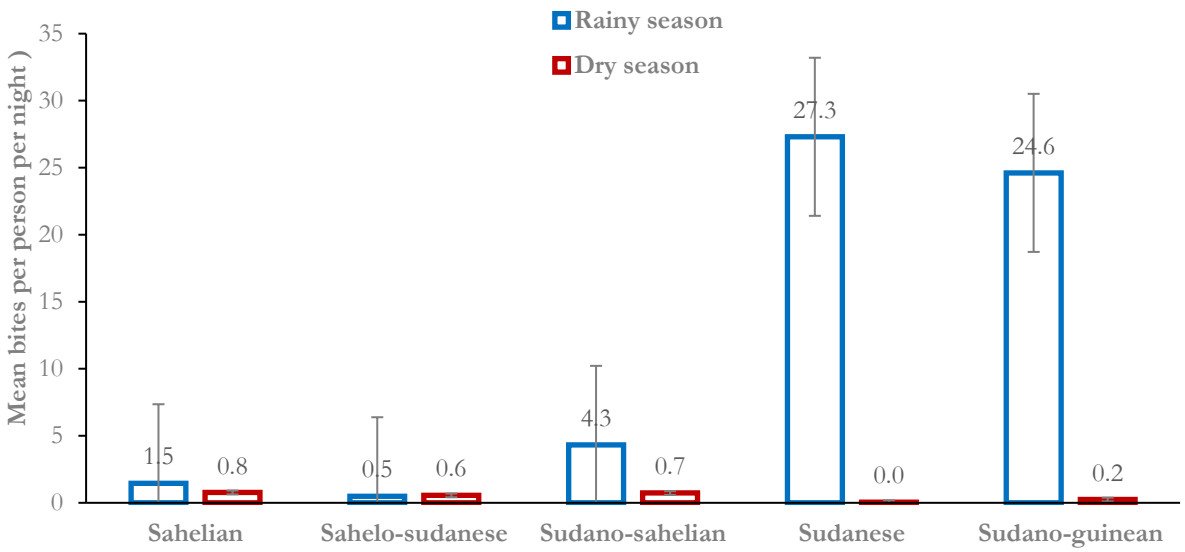
Figure 4: Hourly *An. gambiae* s.l. Human Biting Rate By geographical Area



3.1.2.2 SEASONAL VARIATION OF THE HUMAN BITING RATE OF AN. GAMBIAE S.L.

The mean HBRs were significantly higher in all geographical zones during the rainy season with more than 1 b/p/n except the Sahelo-Sudanese zone, where less than one bite per person-night (<1 b/p/n) was recorded during both dry and rainy season (Figure 5). The highest rates were recorded in the Sudanese (27 b/p/n) and Sudano-Guinean (25 b/p/n) areas during the rainy season while the HBR was quasi nil during the dry season in those zones. However, the HBR of all geographical zones was less than 1b/p/n during the dry period (Annex B).

FIGURE 5: SEASONAL VARIATIONS OF *AN. GAMBIAE* S.L. HUMAN BITING RATE BY GEOGRAPHICAL AREA



3.1.3 *ANOPHELES GAMBIAE* S.L. ENDOPHAGIC RATE

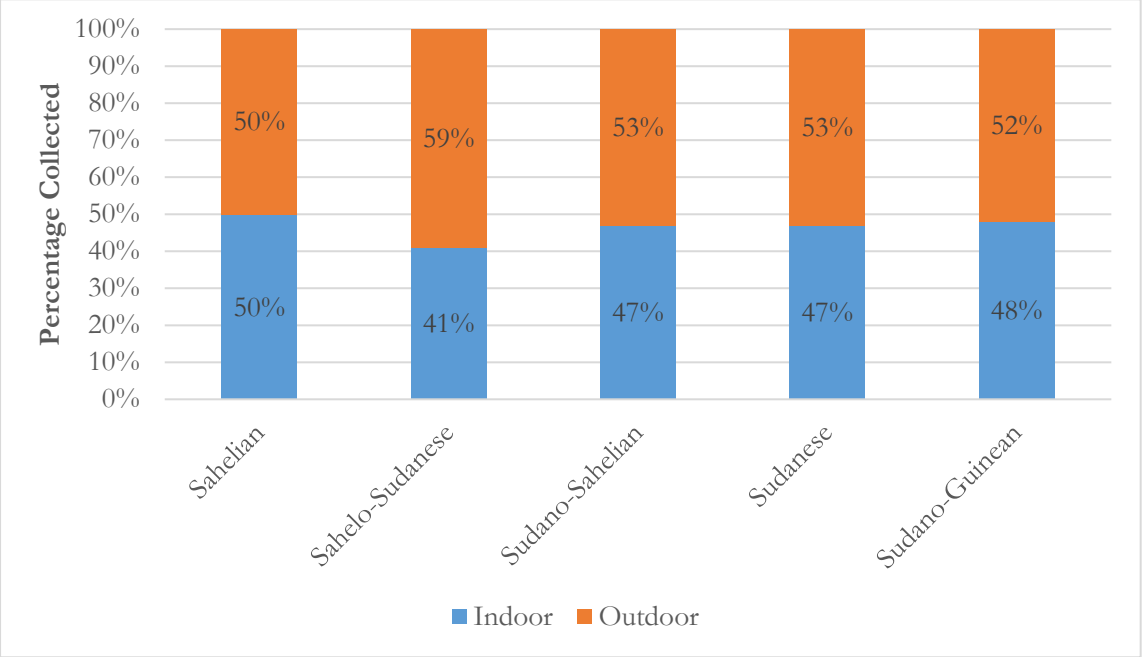
A significantly higher proportion of *An. gambiae* s.l. was collected indoors than outdoors, in all the geographical areas except in the Sahelian zone (Figure 6 & Table 6). Although the proportions of females biting indoors varied between sentinel districts and even between sentinel districts within the same geographical area.

TABLE 6: FEMALE *AN. GAMBIAE* S.L. ENDOPHAGIC RATES BY GEOGRAPHICAL- AREA

Collected	Geographical zones					Total
	Sahelian	Sahelo Sudanese	Sudano Sahelian	Sudanese	Sudano Guinean	
Number collected indoors	54	104	659	2104	3424	6345
Number collected outdoors	53	71	589	1933	3133	5679
Endophagic rates	**0.50†**	**0.59ǂ**	**0.53ǂ**	**0.53ǂ**	**0.52ǂ**	**0.53**

†no significant difference ǂsignificantly higher endophagic rate

FIGURE 6. PROPORTION OF *AN. GAMBIAE* S.L. FEMALES COLLECTED INDOORS AND OUTDOORS USING HLC BY GEOGRAPHICAL ZONE



3.1.4 *ANOPHELES FUNESTUS* S.L. HUMAN BITING RATE

3.1.4.1 ANNUAL BITING CYCLE OF AN. FUNESTUS S.L.

The monthly HBRs of *An. funestus* s.l. were considered for the two zones where larger number where collected during the year. The Sudano-Sahelian zone recorded the highest peak of *An. funestus* s.l. biting rates in March with an approximate mean of 4.1 b/p/n. The Sahelian zone recorded the maximum densities in August and November with less than 1b/p/n (Figure 7). The biting cycle of *An. funestus* s.l. was observed throughout the night particularly in the Sudano-Sahelian zone. The peak biting was observed between 03 a.m. to 05 a.m. both indoors and outdoors (Figure 8).

FIGURE 7: MONTHLY VARIATIONS OF *AN. FUNESTUS* S.L. HUMAN BITING RATE OF THE SAHELIAN AND SUDANO-SAHELIAN GEOGRAPHICAL AREAS

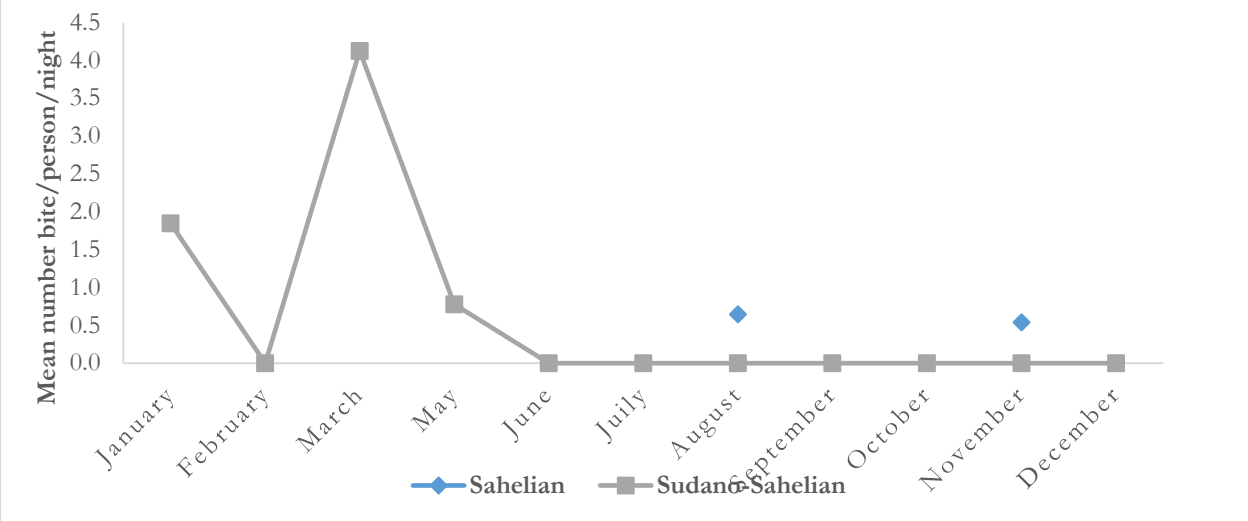
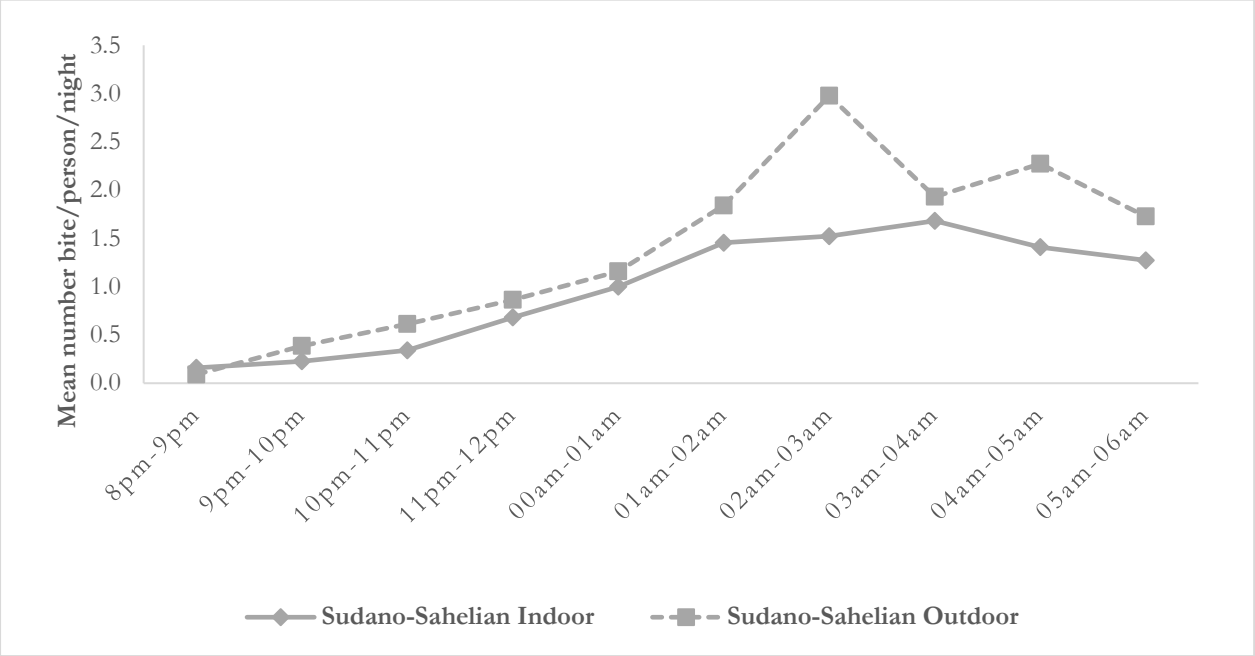


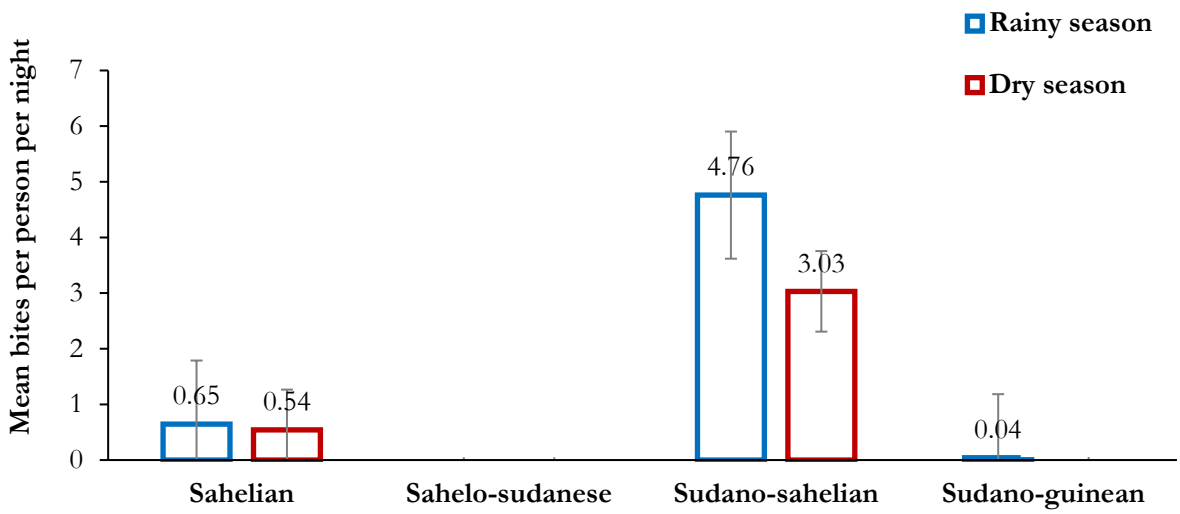
FIGURE 8: HOURLY *AN. FUNESTUS* S.L. HUMAN BITING RATE BY GEOGRAPHICAL AREA



3.1.4.2 SEASONAL VARIATION OF THE HUMAN BITING RATE OF AN. FUNESTUS S.L.

The mean human biting rates of *An. funestus* s.l. were <1 b/p/n in all geographical areas and seasons except the Sudano-Sahelian zone, where the highest HBR was recorded during both dry and rainy season. This was particularly achieved following the densities collected in Ndoffane (Figure 9). Any *An. funestus* s.l. was collected in the Sahelo-Sudanese zone (Annex C).

FIGURE 9: SEASONAL VARIATIONS OF *AN. FUNESTUS* S.L. HUMAN BITING RATE BY GEOGRAPHICAL AREA



3.1.5. *ANOPHELES FUNESTUS S.L. ENDOPHAGIC RATE*

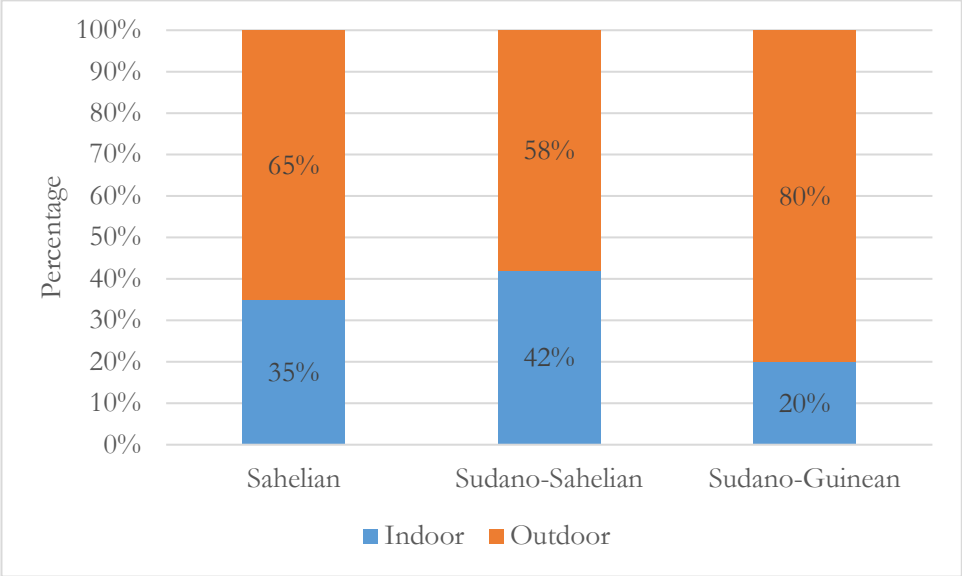
The endophagic rate of *An. funestus* s.l. females was 0.4 in both the Sahelian and Sudano-Sahelian zones, where larger numbers were collected (Table 7).). In the Sudano-Sahelian zone, the endophagic rates were comparable between the dry season and the rainy season (p = 0.06).

Also, in the districts where *An. funestus* s.l. was found, higher outdoor biting rates were recorded (Figure 10).

TABLE 7: ENDOPHAGIC RATE OF HOST-SEEKING OF *AN. FUNESTUS* S.L. BY GEOGRAPHICAL AREA

Collected	Sahelian	Sudano-Sahelian	Total
Number collected indoors	21	429	450
Number collected outdoors	36	610	646
Endophagic rates	0.4	0.4	0.4

FIGURE 10. PROPORTION OF *AN. FUNESTUS* S.L. FEMALES COLLECTED INDOORS AND OUTDOORS USING HLC BY GEOGRAPHICAL ZONE



3.1.5 INDOOR RESTING DENSITIES AND ABDOMINAL STATUS OF FEMALES COLLECTED BY PSC

3.1.5.1 AN. GAMBIAE S.L.

The highest mean *An. gambiae* s.l. indoor resting density (IRD) was recorded in Sudano–Sahelian zone and during both dry and rainy seasons (Figure 11).

However, the mean IRD was higher during the rainy season than the dry season in all the surveyed areas, except the Sahelian area where less than one female was collected per room (IRD <1 female/room (f/r)) in the rainy season (Figure 12). Additionally, the mean IRD across both seasons was less than one female per room in the Sudanese and Sudano-Guinean zones. The IRD varied from 2 f/r in the Sahelo-Sudanese zone to 4 f/r in both the Sahelian and Sudano-Sahelian zone (Annex D).

FIGURE 11: MEAN INDOOR RESTING DENSITY OF *AN. GAMBIAE* S.L. BY GEOGRAPHIC AREA

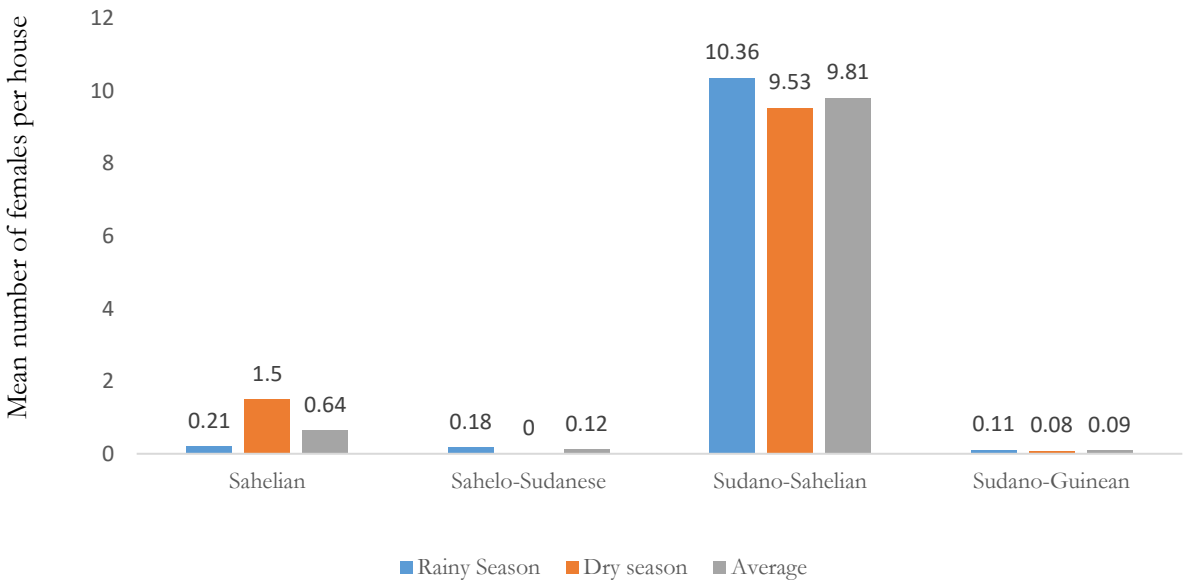


FIGURE 12: MEAN INDOOR RESTING DENSITY OF *AN. GAMBIAE* S.L. BY SENTINEL DISTRICT

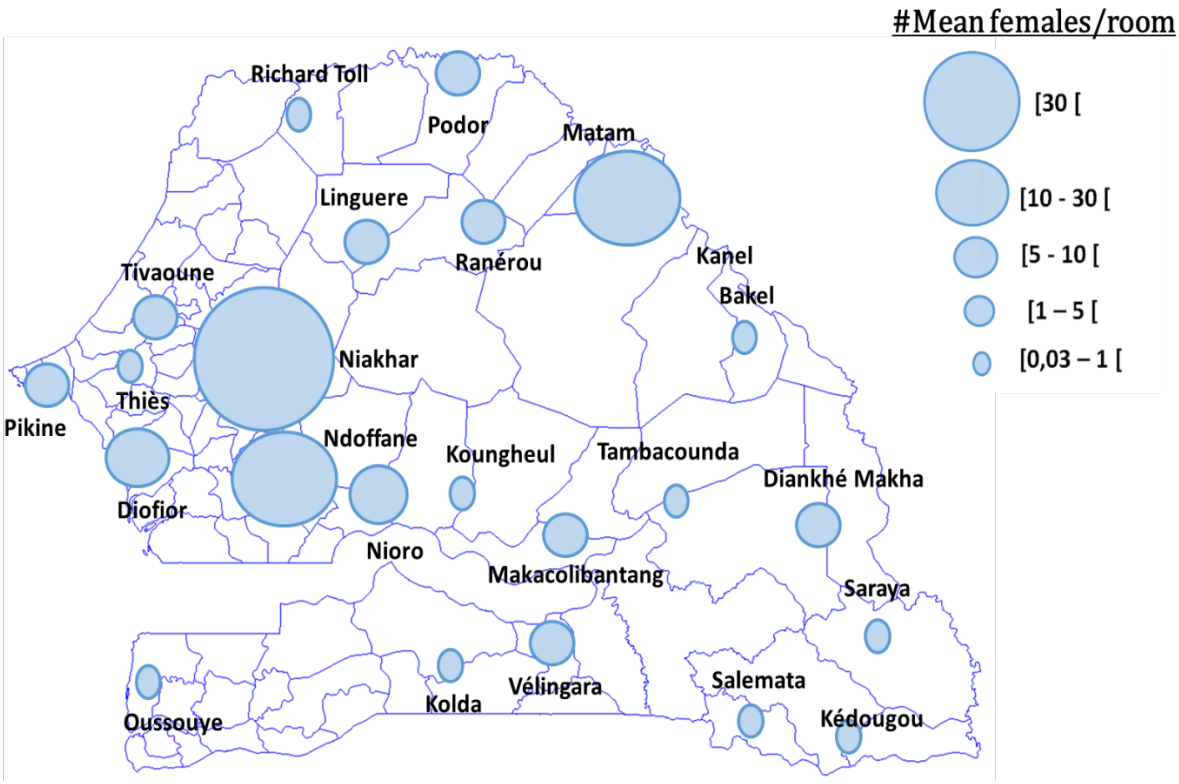
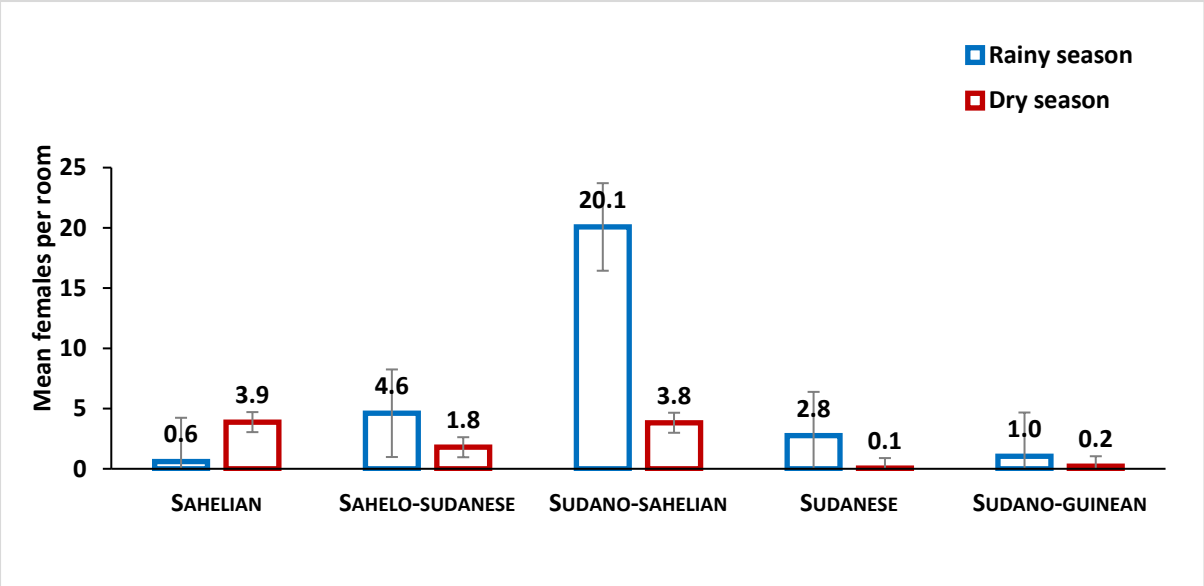


FIGURE 13: SEASONAL VARIATIONS OF *AN. GAMBIAE* S.L. RESTING DENSITIES BY GEOGRAPHICAL AREA



The proportion of blood-fed females found inside human dwellings (Table 8) was significantly low in the Sudanese zone in both the rainy season and the dry season ($p < 0.05$) compared to the other zones (Annex E). In the Sahelian regions, the proportions of blood-fed females were significantly higher during the dry season ($p < 0.05$), conversely to the Sahelo-Sudanese and Sudano-Sahelian zones.

TABLE 8: THE ABDOMINAL STATUS OF INDOOR RESTING FEMALES OF *AN. GAMBIAE* S.L. BY GEOGRAPHICAL AREA

Districts	Total		Unfed		Blood-fed		Half-gravid		Gravid	
	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS
Sahelian	62	155	4 (6.5%)	0%	34 (54.8%)	126 (81.3%)	2 (3.2%)	0%	22 (35.5%)	29 (18.7%)
Sahelo-Sudanese	1482	374	29 (2.0%)	0%	999 (67.4%)	291 (77.8%)	75 (5.1%)	4 (1.1%)	380 (25.6%)	79 (21.1%)
Sudano-Sahelian	4015	917	337 (8.4%)	41 (4.5%)	2232 (55.6%)	550 (60.0%)	334 (8.3%)	156 (17.0%)	1112 (27.7%)	170 (18.5%)
Sudanese†	330	7	26 (7.9%)	0%	124 (37.6%)	2 (28.6%)	87 (26.4%)	4 (57.1%)	93 (28.2%)	1 (14.3%)
Sudano-Guinean	228	42	12 (5.3%)	6 (14.3%)	155 (68.0%)	22 (52.4%)	3 (1.3%)	4 (9.5%)	58 (25.4%)	10 (23.8%)

Note: RS = rainy season, DS = dry season
† proportion of blood-fed females significantly lower than in other areas

3.1.5.2 *AN. FUNESTUS* S.L.

The highest *An. funestus* s.l. average IRD was found in the Sudano-Sahelian zone with particularly higher density collected in the site of Nioro (13 f/r) (Figure 14). Additionally, the IRD was relatively higher during the rainy season (Figure 15) than the dry season in the Sudano-Sahelian zone.

FIGURE 14: INDOOR RESTING DENSITY OF *AN. FUNESTUS* S.L. FEMALES BY DISTRICT

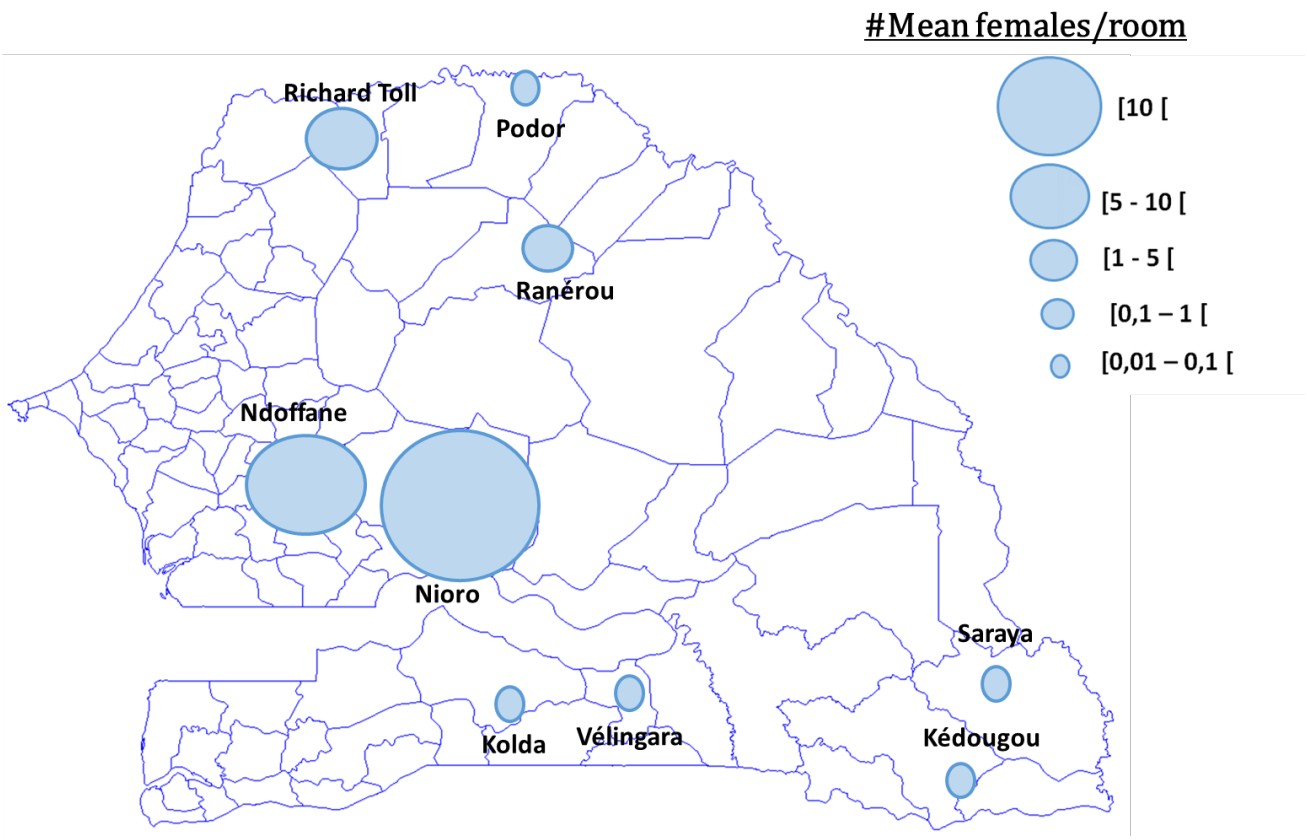
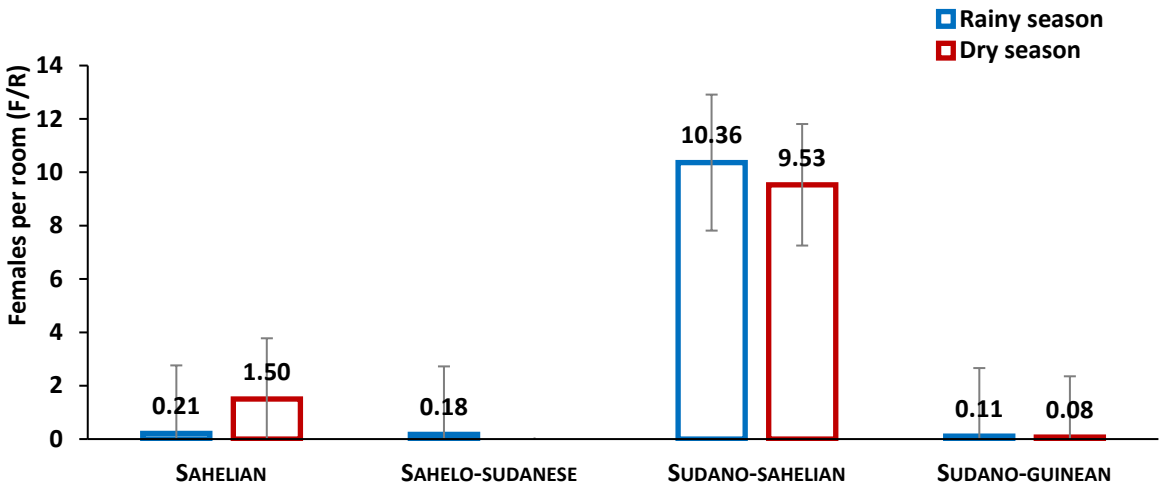


FIGURE 15: SEASONAL VARIATIONS OF *AN. FUNESTUS* S.L. INDOOR RESTING DENSITIES BY GEOGRAPHICAL AREA



The proportion of blood-fed females was significantly lower in the Sudano-Sahelian zone than in other zones, both during the dry season ($p = 0.02$) and the rainy season ($p = 0.04$) (Table 9). In contrast, there was no significant seasonal variation in the proportion of blood-fed *An. funestus* s.l. females collected through PSC, no matter the sentinel district where they were found (e.g., Sahelian: $p = 0.8$; Sudano-Sahelian: $p = 0.3$ and Sudano-Guinean: $p = 0.6$).

TABLE 9: THE ABDOMINAL STATUS OF INDOOR RESTING FEMALES OF *AN. FUNESTUS* BY GEOGRAPHICAL AREA

Zone	Total		Unfed		Blood-fed		Half-gravid		Gravid	
	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS
Sahelian	17	60	0%	1 (1.7%)	12 (70.6%)	44 (73.3%)	3 (17.6%)	3 (5.0%)	2 (11.7%)	12 (20.0%)
Sudano-Sahelian†	829	1525	59 (7.1%)	139 (9.1%)	485 (58.5%)	862 (56.5%)	141 (17.0%)	205 (13.4%)	144 (17.4%)	319 (20.9%)
Sudano-Guinean	18	12	1 (5.6%)	3 (25.0%)	15 (83.3%)	9 (75.0%)	1 (5.6%)	0%	1 (5.6%)	0%

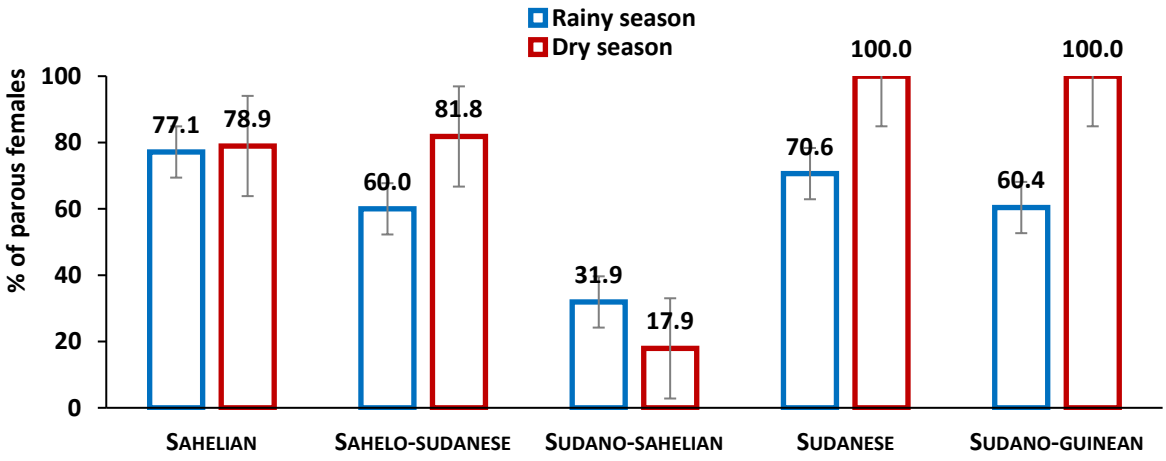
Note: RS = rainy season, DS = dry season
† proportion of blood-fed females significantly lower than in other areas

3.1.6 PARITY RATE

3.1.6.1 *AN. GAMBIAE S.L.*

The mean parity rate of female *An. gambiae* s.l. in both the rainy and dry seasons was significantly high in all the geographical zones except in the Sudano-Sahelian area. The mean parity rates were above 60% in all those sites. The mean parity rate was higher during the dry season, except in the Sudano-Sahelian zone (Figure 16 and the Annex G) showing that the females collected were particularly old.

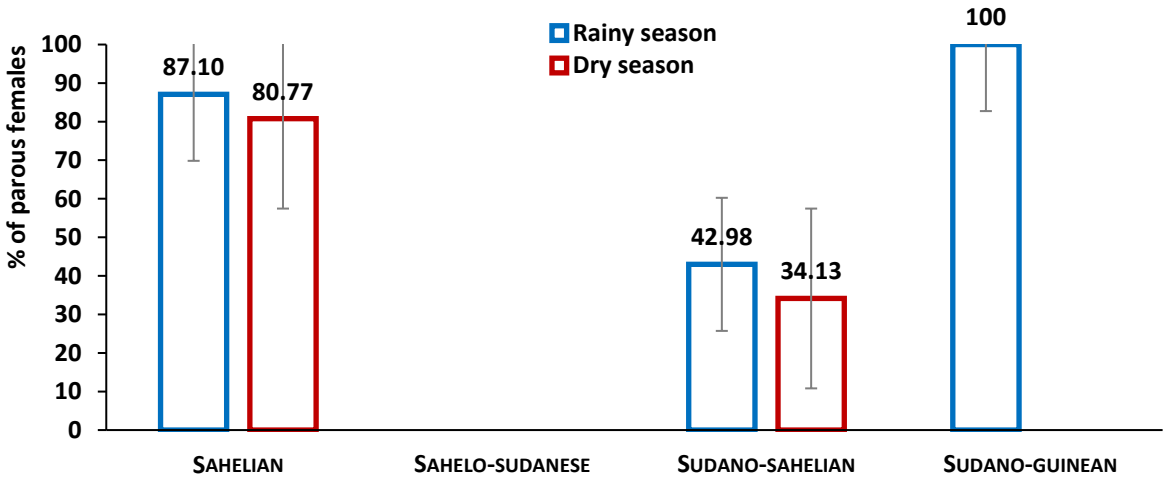
FIGURE 16: SEASONAL VARIATIONS OF *AN. GAMBIAE* S.L. PARITY RATE BY GEOGRAPHICAL AREA



3.1.6.2. *AN. FUNESTUS S.L.*

The mean parity rate of the female *An. funestus* s.l. was significantly high in the Sahelian zone ($p < 0.005$). It was lower in the Sudano-Sahelian zone than in the Sahel, during both the rainy and the dry seasons (Figure 17, Annex I).

FIGURE 17: SEASONAL VARIATIONS OF *AN. FUNESTUS* S.L. PARITY RATE BY GEOGRAPHICAL AREA



3.2 MALARIA VECTOR SUSCEPTIBILITY TO INSECTICIDES

WHO insecticide susceptibility tests were carried out only against *An. gambiae* s.l., the main vector species collected in all the surveyed sites. CDC bottle assays were also conducted in selected sites using chlorfenapyr insecticide. Annex H presents the insecticide susceptibility testing activities carried out, by district.

3.2.1 WHO INSECTICIDE SUSCEPTIBILITY TEST

The insecticide susceptibility test using the WHO method revealed that natural populations of *An. gambiae* s.l. were resistant to all the three pyrethroids tested (deltamethrin, permethrin, and alpha-cypermethrin) in almost all the sentinel districts, except Nioro (in the Sudan-Sahelian zone), where t susceptibility to deltamethrin was recorded (Figure 18). *An. gambiae* s.l. were susceptible to pirimiphos-methyl at all sites surveyed, except in Rufisque (Sahelo-Sudanese zone) where the vector populations showed probable resistance to the insecticide (Figure 19, Annex J1-J2).

In the Sudano-Sahelian and Sahelo-Sudanese zones, the vast majority of the populations of *An. gambiae* s.l. were susceptible to bendiocarb (Figure 19). Only the populations tested in Diamniadio (Sahelo-Sudanese zone) and Kaolack (Sudano-Sahelian) were likely resistant to bendiocarb.

Possible resistance to bendiocarb was also recorded in Podor (Sahelian zone) and in the three districts in Matam region in the Sahelo-Sudanese zone. In the Sudano-Guinean zone, *An. gambiae* s.l. populations from Kedougou and Velingara were, respectively, susceptible and resistant to bendiocarb (Figure 19). Those from Kolda and Oussouye showed probable resistance to bendiocarb.

3.2.2 INTENSITY OF RESISTANCE TO PYRETHROIDS

High resistance intensity to deltamethrin was observed in most of the sentinel districts of each geographical zone (Figure 18 and Annex J2). The intensity was variable for alpha-cypermethrin and permethrin (moderate or high) across the districts. This shows that the effectiveness of all vector control measures using pyrethroid insecticides only could be threatened by the resistance of the local population of malaria vectors.

3.2.3 TESTS WITH SYNERGISTS

In all sentinel districts, the pre-exposure of population to PBO (a synergist) increased the mortality rate of resistant females to the three pyrethroids, particularly for deltamethrin and permethrin (Figure 20) and could therefore support any deployment of PBO incorporated ITNS where substantial increment of the mortality was observed.

FIGURE 18: RESISTANCE STATUS AND INTENSITY OF THE RESISTANCE OF *AN. GAMBIAE* S.L. POPULATIONS EXPOSED TO PYRETHROIDS

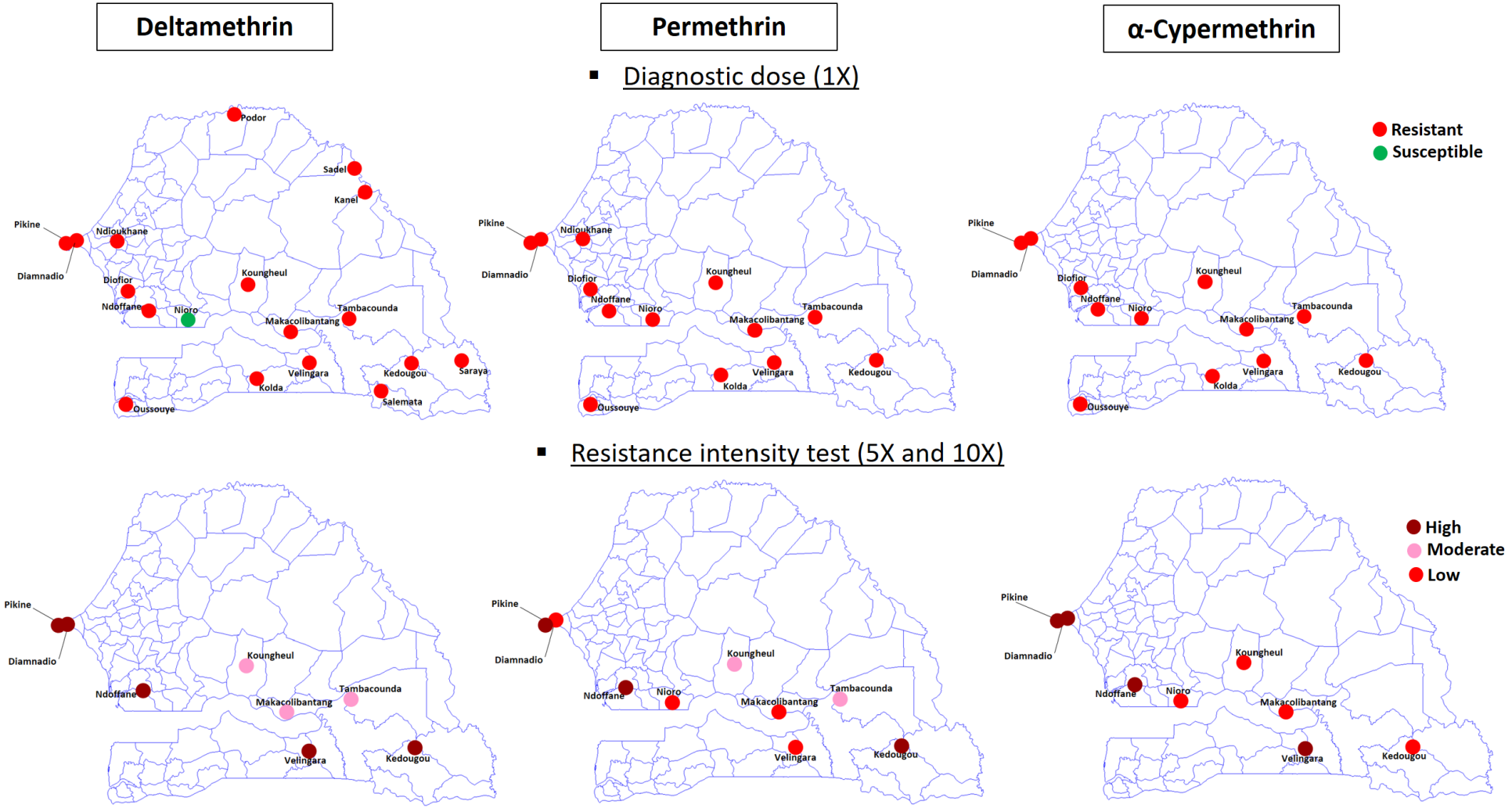


FIGURE 19: RESISTANCE STATUS OF *AN. GAMBIAE* S.L. POPULATIONS TO THE PIRIMIPHOS-METHYL AND BENDIOCARB

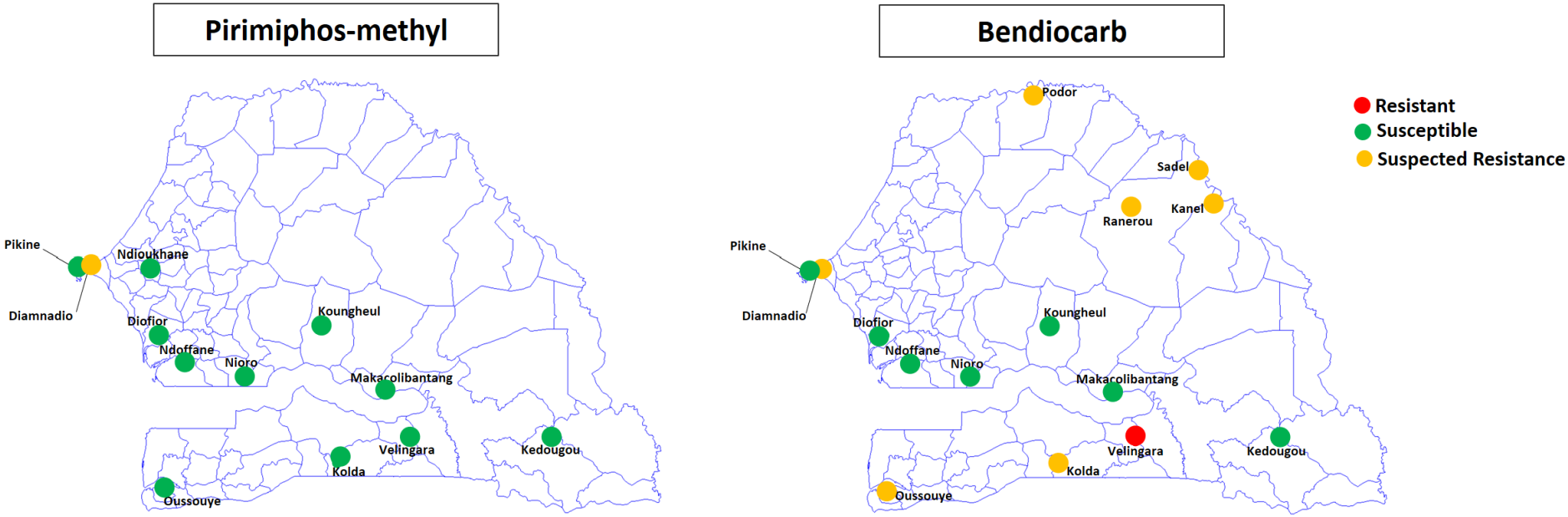
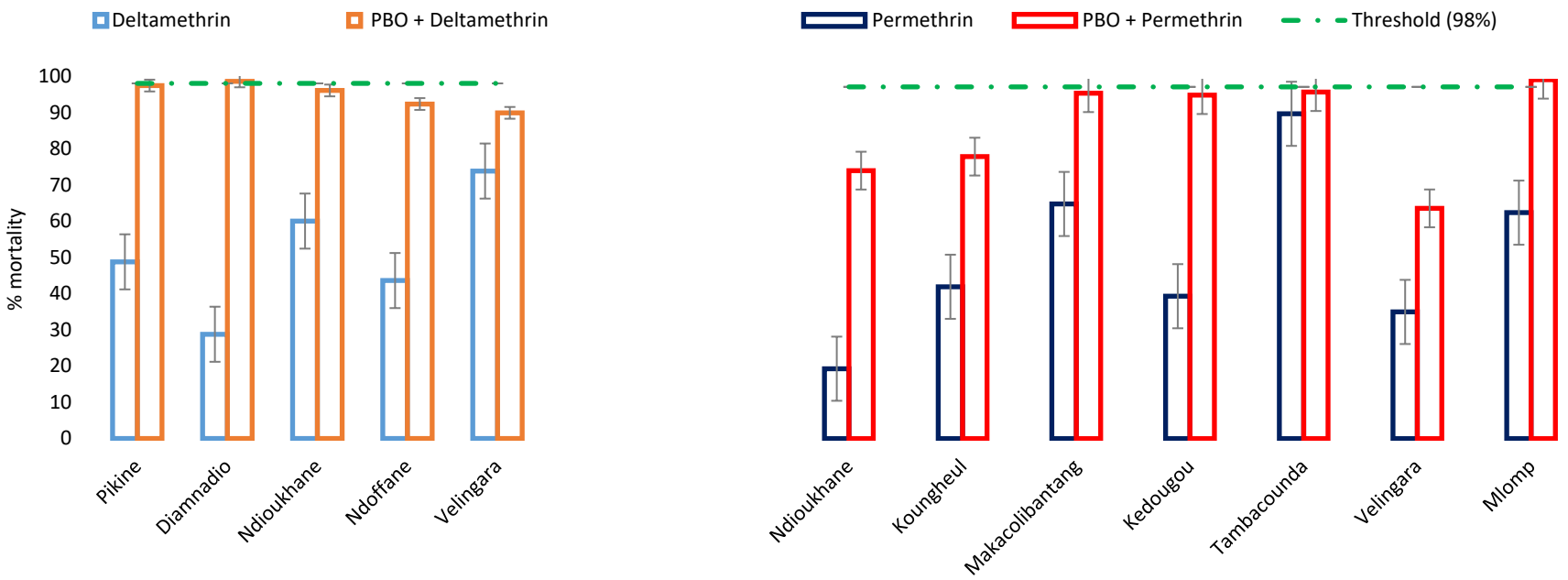


FIGURE 20: MORTALITY RATE OF *AN. GAMBIAE* S.L. EXPOSED TO THE DELTAMETHRIN AND PERMETHRIN BEFORE AND AFTER PRE-EXPOSURE TO PBO



3.2.4 SUSCEPTIBILITY OF *AN. GAMBIAE* S.L. TO CLOTHIANIDIN

With 100% of mortality reached before the end of the seventh day post exposure, the populations of *An. gambiae* s.l. were susceptible to clothianidin in all sites where the tests were conducted (Figure 21).

3.2.5 SUSCEPTIBILITY OF *AN. GAMBIAE* S.L. TO CHLORFENAPYR

All the tested populations of *An. gambiae* s.l. were resistant to chlorfenapyr after three days at the lowest dose tested (100µg/bottle) (Figure 22), while only *An. gambiae* s.l. populations from Koungheul and Kedougou remained resistant at the highest dose of 200µg/bottle.

FIGURE 21: SUSCEPTIBILITY OF *AN. GAMBIAE* S.L. POPULATIONS TO CLOTHIANIDIN BY DISTRICT

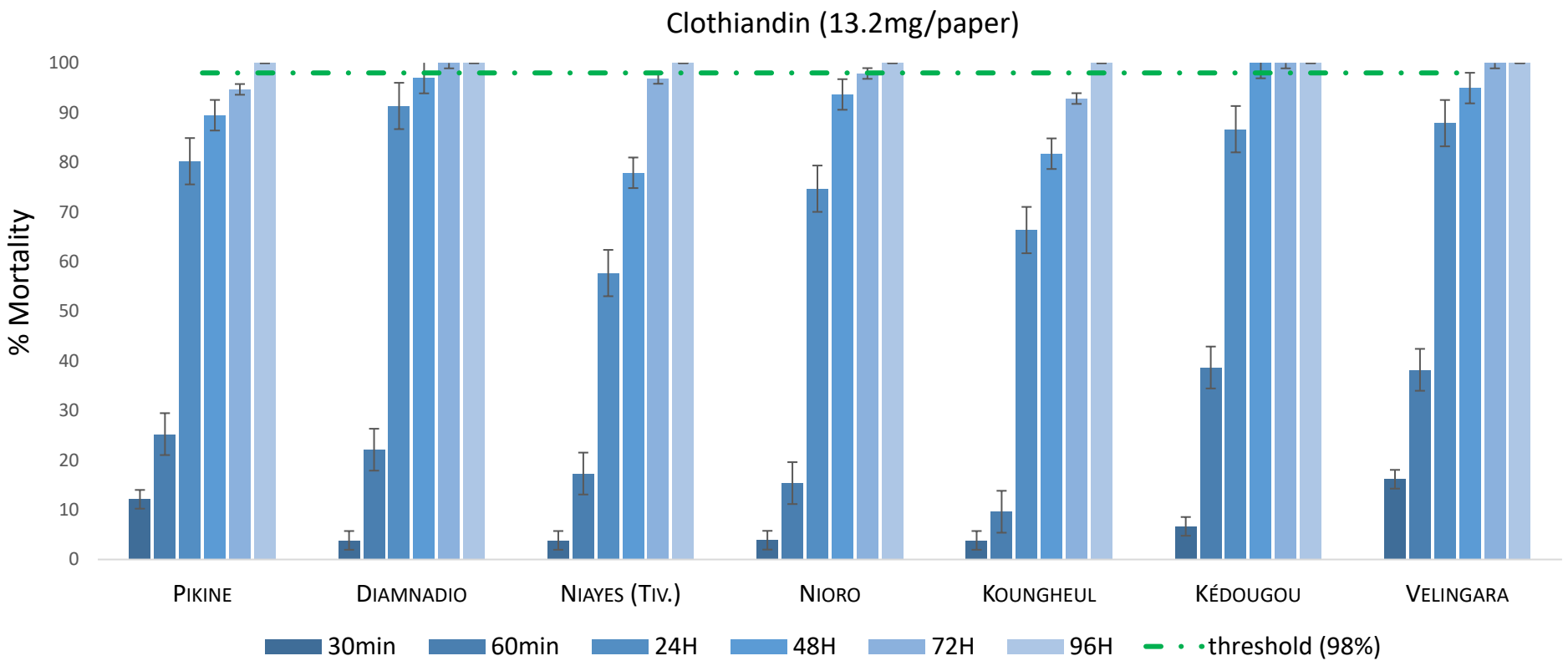
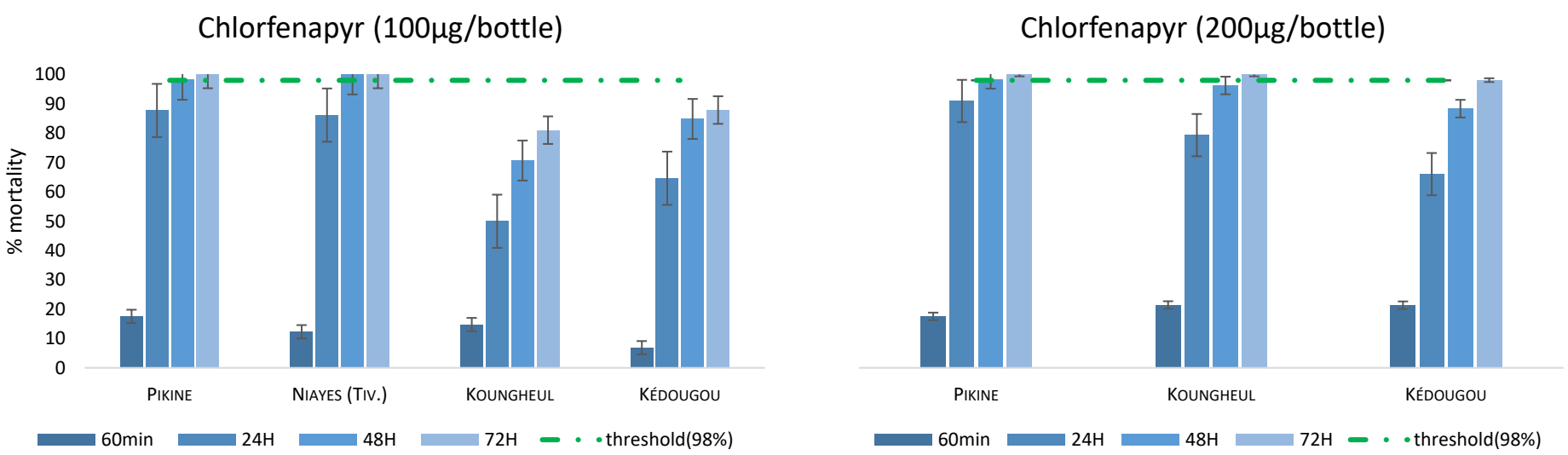


FIGURE 22: SUSCEPTIBILITY OF *AN. GAMBIAE* S.L. POPULATIONS TO CHLORFENAPYR BY DISTRICT



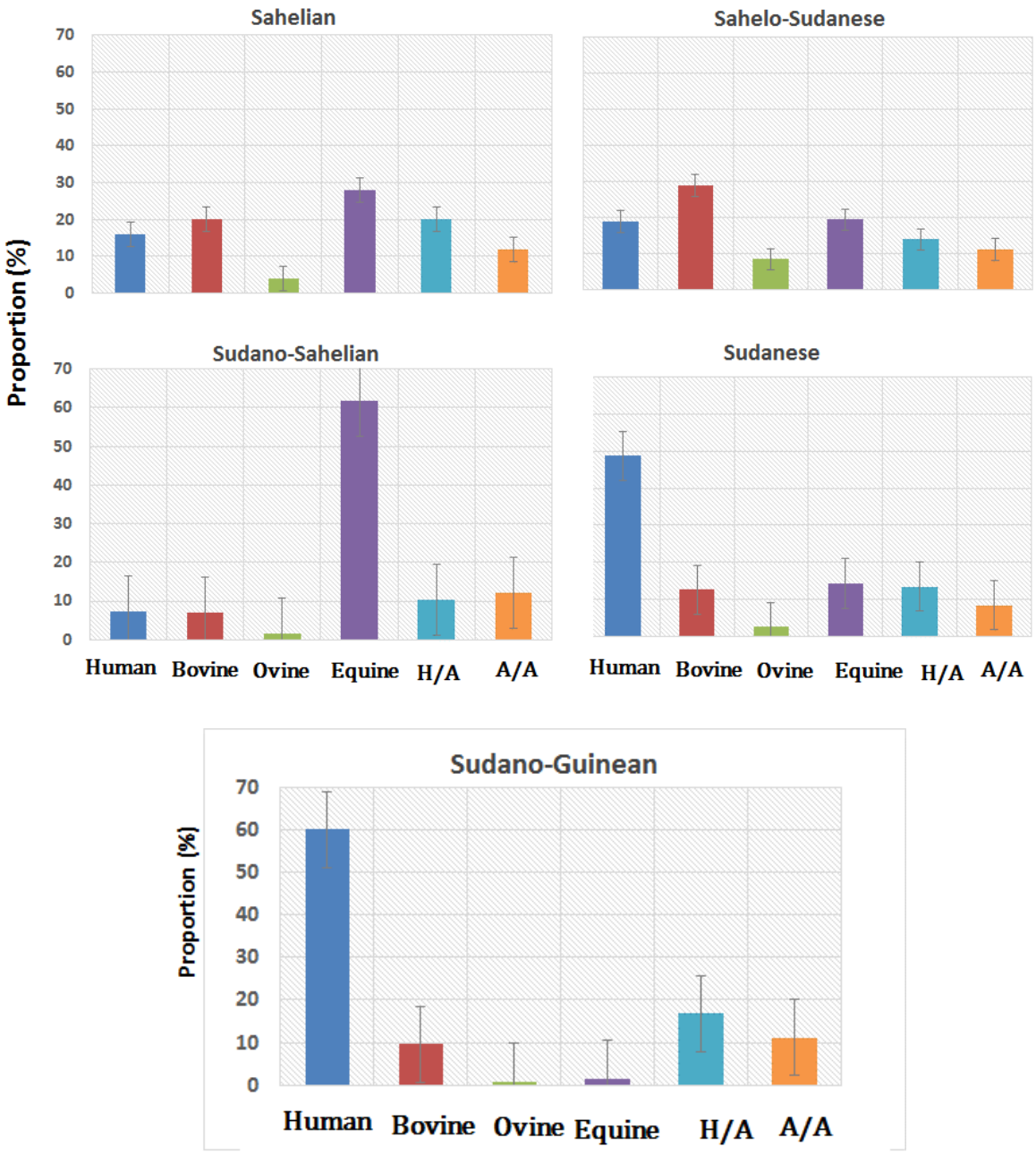
3.3 LABORATORY ANALYSIS

3.3.1 ORIGIN OF BLOOD MEALS

The trophic profile of endophilic female *An. gambiae* s.l. by geographical areas is shown in Figure 23 and Annexes K and L. In the Sudanese and Sudano-Guinean zones, female *An. gambiae* s.l. fed mainly on humans, with respective anthropophilic rates of 62% (74/119) and 77% (96/125). The mean anthropophilic rate was significantly lower in the Sahelian (36%; 9/25), Sahelo-Sudanese (33%; 59/181), and Sudano-Sahelian (18%; 67/381) zones ($p < 0.05$).

In the Sahelian zone, horses (28%; 7/25) and cows (20%; 5/25) were the main alternative animals host for *An. gambiae* s.l. females. In the Sudano-Sahelian zone, it was the horse (80%: 306/381).

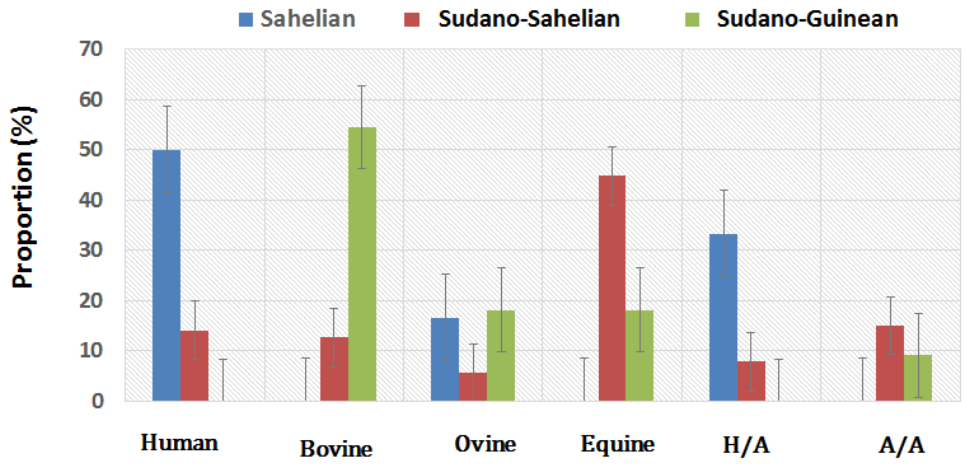
FIGURE 23: BLOOD MEAL SOURCES OF *AN. GAMBIAE* S.L. BY GEOGRAPHICAL AREA



Note: H/A: mixed human-animal; A/A.: mixed animal-animal

The anthropophilic rate of endophilic females of *An. funestus* s.l. was significantly higher (p <0.05) in the Sahelian zone (83%: 10/12) than in the Sudano-Sahelian zone (22%: 67/306), and all the females collected in the Sudanese-Guinean zone fed on animals (0/11). Cows (54%: 6/11) and horses (45%: 137/306) were the main animal hosts for *An. funestus* s.l. in the Sudano-Guinean and the Sudano-Sahelian zones, respectively (Figure 24 and Annex M).

FIGURE 24: BLOOD MEAL SOURCES OF *AN. FUNESTUS* S.L. FEMALES BY GEOGRAPHIC AREA



Note: H/A: mixed human-animal; A/A.: mixed animal-animal

3.3.2 *PLASMODIUM FALCIPARUM* INFECTION RATE OF VECTOR POPULATIONS

Table 14 describes the *Pf* infection rates (or sporozoite rates (SR) of *An. gambiae* s.l. and *An. funestus* s.l. females collected using HLCs. The *Pf* infection rates varied by geographical areas, with highest rate of infected *An. gambiae* s.l. females in the Sahelian and Sahelo-Sudanese zones (p < 0.05). No difference was observed between the sporozoite infection rate of *An. funestus* s.l. was recorded in the Sahelian (3.1%: 2/63) and the Sudano-Sahelian (0.9%: 3/339) zones representing the two sites where larger number of *An. funestus* s.l. was collected ((P = 0.375).

TABLE 14: *PLASMODIUM FALCIPARUM* SPOROZOITE RATE OF ANOPHELES FEMALES BY GEOGRAPHICAL AREA

Geographical zone	*An. gambiae s.l.*			*An. funestus s.l.*		
	Tested	Positive	SR†	Tested	Positive	SR
Sahelian	107	3	0.028	63	2	0.031
Sahelo-Sudanese	191	7	0.037	0	0	0
Sudano-Sahelian	356	0	0	339	3	0.009
Sudanese	245	5	0.020	0	0	0
Sudano-Guinean	547	15	0.027	0	0	0

† Significant difference

Infected females of *An. gambiae* s.l. were found in all the surveyed geographical areas, except the Sudano-Sahelian zone, where no infected female was recorded out of the 356 mosquitoes analyzed (Annex N). The highest CSP rate was found in the Sahelo-Sudanese zone (3.7%). Infected females of *An. funestus* s.l. were found in the Sahelian and Sudano-Sahelian zones, the only sites where tests were performed.

Infected *An. gambiae* s.l. females were found from July to December in the Sudanese and Sudano-Guinean zones (Annex O). *An. funestus* s.l. infected females were found during the end of the rainy season (November) and in the middle of the dry season (March-May). None of the female *An. pharoensis* and *An. nili* that were tested was found infected (Annex P).

3.3.3 Entomological Inoculation Rate

The average EIR of *An. gambiae* s.l. varied by zone, with the lowest EIR recorded in the Sahelian zone (0.021 infected bites per person per night (ib/p/n)) and the highest recorded in the Sudano-Guinean zone (0.35 ib/p/n ($p > 0.05$) (Table 15). At the district level, the highest EIR was recorded in the district of Kedougou (0.64 ib/p/n) (Figure 18 and Annex Q-R). Monthly values of EIR are presented in annex S.

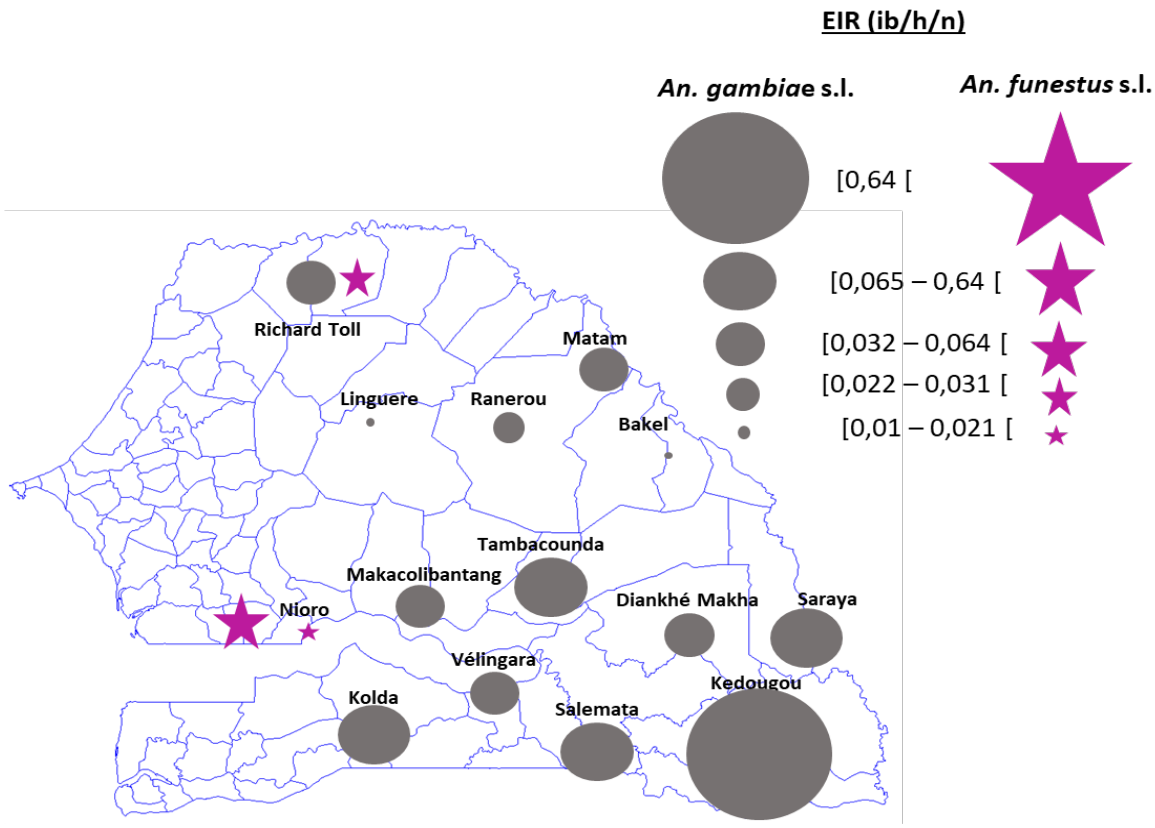
Table 15: Entomological Inoculation Rate (EIR) of *An. gambiae* s.l. and *An. funestus* s.l. Females by Geographic Area

Geographical zone	*An. gambiae* s.l.			*An. funestus*		
	HBR	SR	EIR	HBR	SR	EIR
Sahelian	0.74	0.029	0.021	0.744	0.034	0.025
Sahelo-Sudanese	0.616	0.037	0.023	-	-	-
Sudano-Sahelian	2.36	0	0	1.967	0.009	0.017
Sudanese	16.4	0.02	**0.33**	-	-	-
Sudano-Guinean	12.9	0.03	**0.35**	-	-	-

Note: BR = biting rate; CSI = circumsporozoite index; EIR = entomological inoculation rate

Infected *An. funestus* s.l. were collected in Richard Toll district, but the highest EIR was recorded in Ndoffane (Figure 25 and Annex R). Although the EIR has increased in the Sahelian zone (Richard Toll district) and Sahelo-Sudanese zone (Matam and Ranerou districts) compared to the data collected in 2018, the transmission risk remains mostly in the southeastern part of the country (Sudanese and Sudano-Guinean zones), especially in the regions of Kolda, Tambacounda, and Kedougou.

Figure 25: Entomological Inoculation Rate of *An. gambiae* s.l. and *An. funestus* s.l. in the Surveyed Districts



3.3.4 SPECIES COMPOSITION OF THE *GAMBIAE* COMPLEX

Figure 26 presents the proportions of the different members of the *An. gambiae* complex across the geographical areas surveyed. Overall, *An. arabiensis* was the most abundant species in the Sahelian, Sahelo-Sudanese, and Sudano-Sahelian zones, in the proportions, of 97.33%; 98.35%, and 96.01, respectively. In the Sudanese and Sudano-Guinean zones, *An. gambiae* was predominant (Figure 26 and Annex T).

Figure 27 presents the composition and distribution of the species of the *An. gambiae* complex by district. The presence of *An. melas* was recorded only in the Sudano-Sahelian zone, where six females were collected in Ndoffane (Annex U).

FIGURE 26: SPECIES COMPOSITION WITHIN THE *AN. GAMBIAE* COMPLEX BY GEOGRAPHICAL AREA

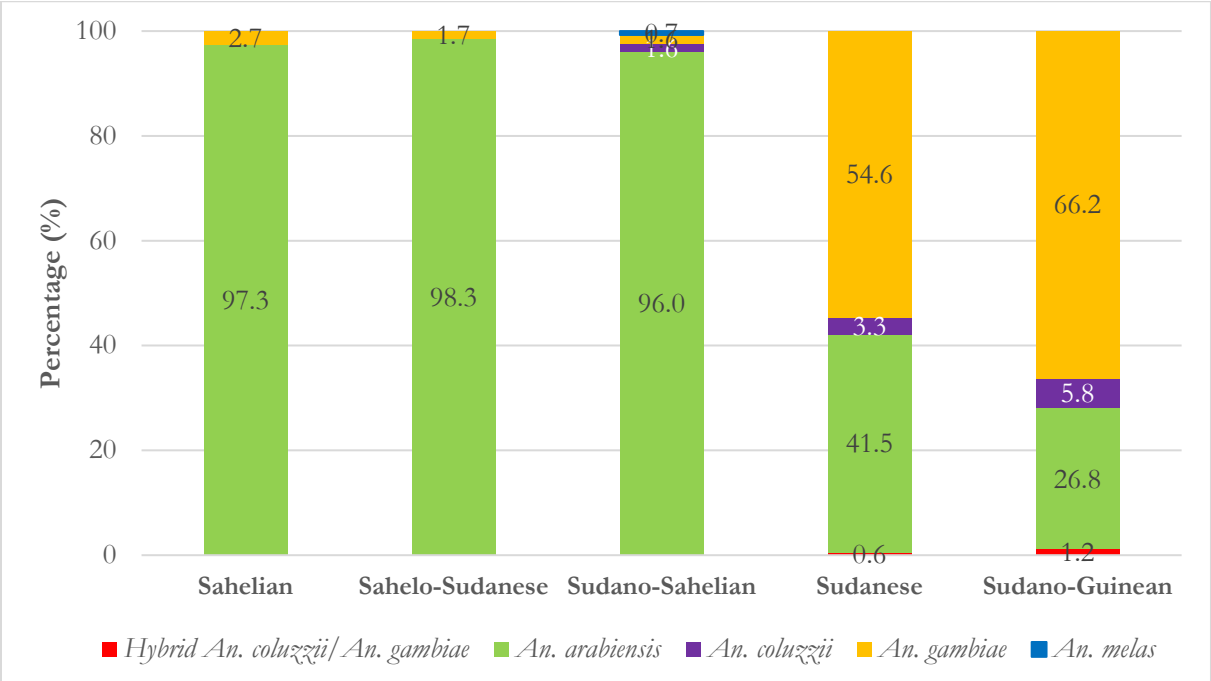
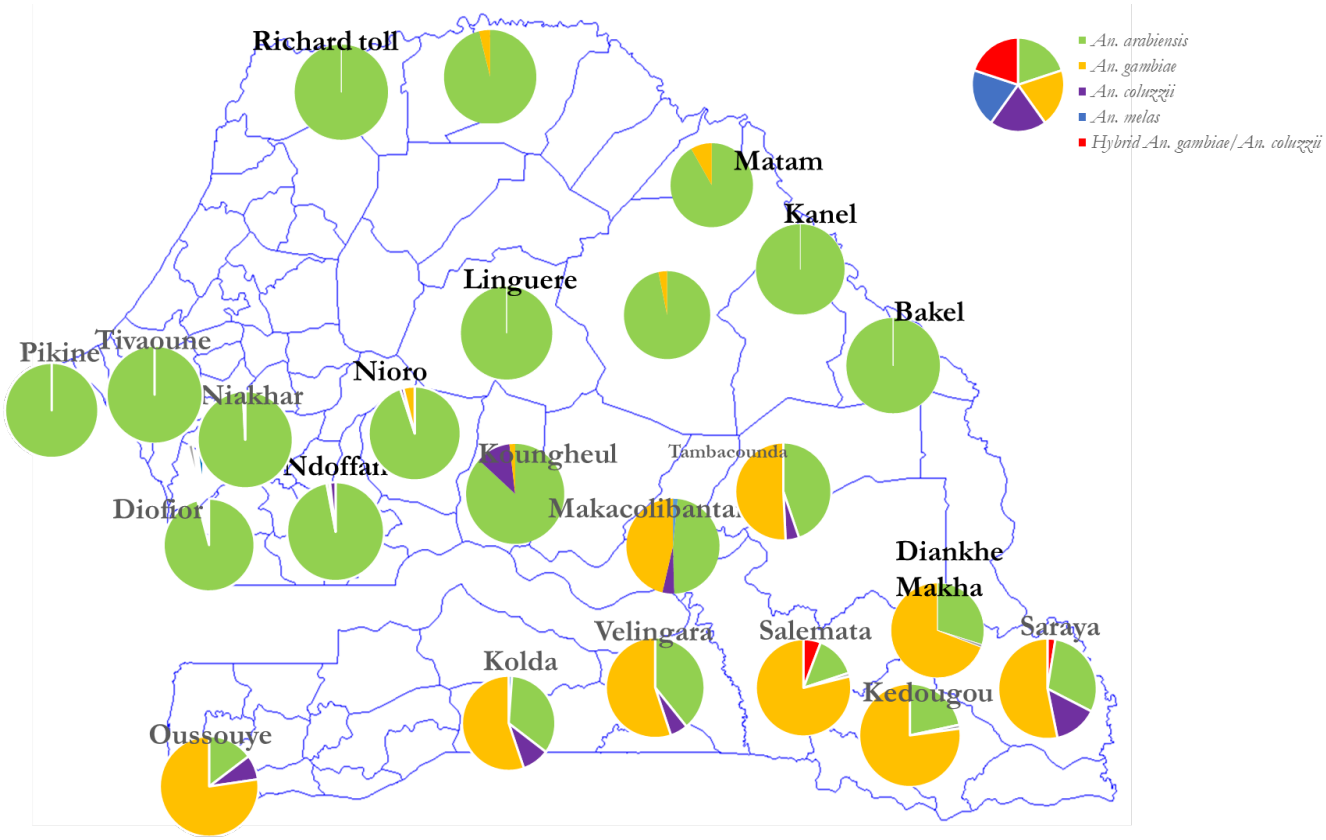


FIGURE 27: SPECIES COMPOSITION AND DISTRIBUTION OF *AN. GAMBIAE* COMPLEX SPECIES BY DISTRICT



3.3.5 MOLECULAR CHARACTERIZATION OF TARGET SITE RESISTANCE MUTATIONS (*KDR* AND ACE 1) IN *AN. GAMBIAE* S.L.

Both the *kdr*-west and *kdr*-east, conferring cross-resistance to pyrethroids and DDT, and the *Ace* 1^R mutation, conferring cross-resistance to carbamates and organophosphates, were investigated for *An. gambiae* s.l. populations.

3.3.6 *KDR* MUTATIONS

ALLELIC FREQUENCIES

Table 16 and Figure 28 show the allelic frequencies of the *kdr*-west and *kdr*-east mutations for *An. gambiae* s.l. populations in the different districts monitored.

For both districts in the Sahelian zone (Richard Toll and Podor) and some districts in the Sahelo-Sudanese zone (Matam, Kanel, Bakel, Ranerou, and Linguere), only the *kdr*-west mutation was screened in both *Anopheles* collected in HLCs and PSCs. The mutation was found in all the sentinel sites, with allelic frequencies of more than 60% (Table 16).

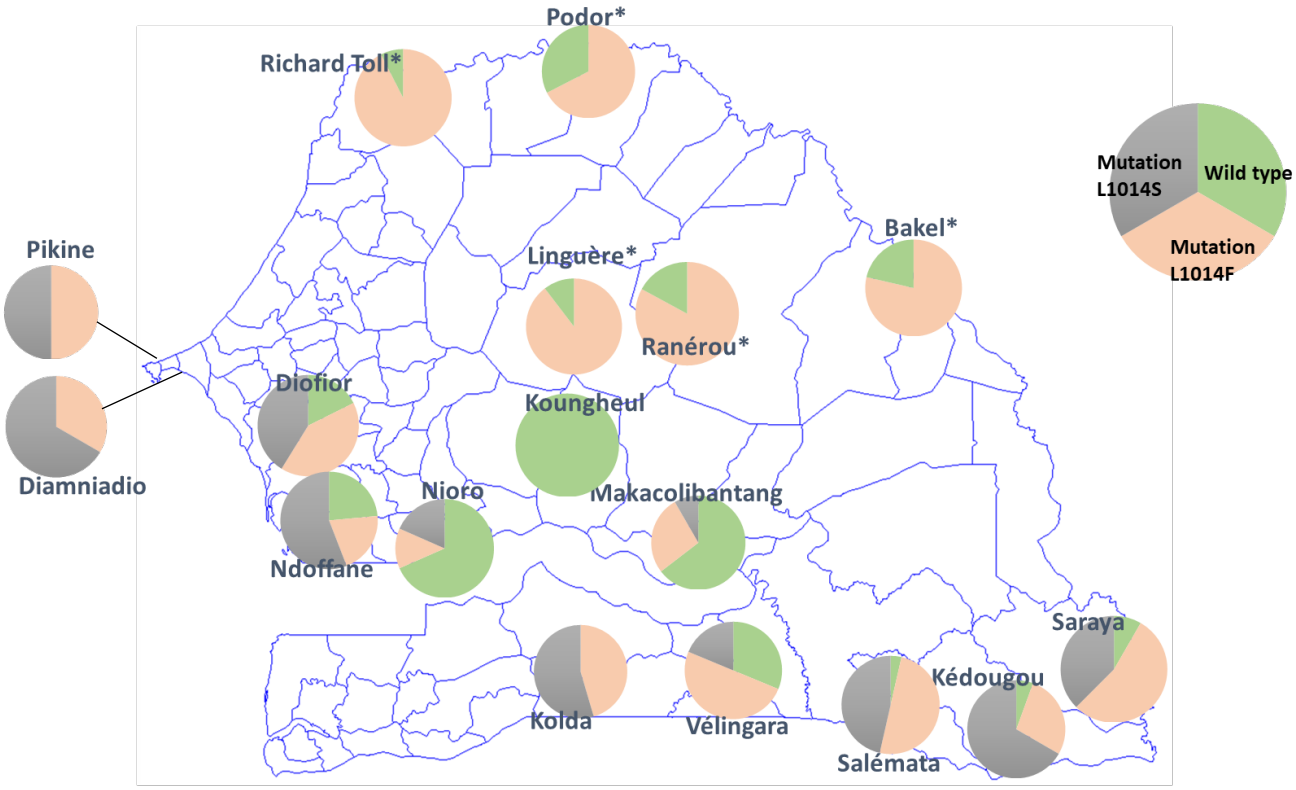
In other districts, where both *kdr*-west and *kdr*-east were investigated, results showed the involvement of both mechanisms in the resistance of the *An. gambiae* s.l. populations in all the sentinel districts, except in Koungheul, where they were both absent among the populations tested (Table 16).

Overall, the presence of the *kdr*-west mutation was high in the district of Richard Toll (92.86%), while the *kdr*-east mutation was high in the districts of Kedougou (66.67%) and Diamniadio (66.67%).

The resistant heterozygous genotype involving both *kdr*-west and *kdr*-east was mostly frequent in the Sudanese zone, particularly in Salemata, where 26 out of the 28 screened carried both *kdr* alleles.

The absence of the susceptible wide-type allele in the urban *An. gambiae* s.l. populations of Dakar and Diamniadio suggests a high insecticide selection pressure, which should be further investigated.

FIGURE 28: ALLELIC FREQUENCIES OF *KDR* MUTATIONS IN *AN. GAMBIAE* S.L. POPULATIONS BY DISTRICT



*Only L1014F *(kdr*-west) was investigated

TABLE 16: GENOTYPIC AND ALLELIC FREQUENCIES OF *KDR*-WEST AND *KDR*-EAST MUTATIONS IN *AN. GAMBIAE* S.L. BY DISTRICT

Geographical zone	District	N	Genotypes						Allelic Frequency (%)		
			SS	SRw	SRe	RwRw	ReRw	ReRe	S	Rw	Re
Sahelian	Richard Toll	42	3	-	-	39	-	-	3	93	-
	Podor	56	17	-	-	39	-	-	24	70	-
Sahelo-Sudanese	Bakel	46	10	-	-	36	-	-	13	78	-
	Kanel	10	1	-	-	9	-	-	1	90	-
	Linguere	46	5	-	-	41	-	-	6	89	-
	Matam	50	2	-	-	48	-	-	2	96	-
	Ranerou	44	8	-	-	36	-	-	9	86	-
	Pikine	15	0	0	0	0	15	0	0	50	50
	Diamnadio	24	0	0	0	2	12	10	0	33	67
Sudano-Sahelian	Diofior	17	3	0	0	2	10	2	18	41	41
	Ndoffane	17	4	0	0	0	7	6	24	21	56
	Nioro	19	13	0	0	0	5	1	68	13	18
	Koungheul	15	15	0	0	0	0	0	100	0	0
Sudanese	Makacolibantang	24	8	12	3	0	1	0	65	27	8
Sudano-Guinean	Saraya	12	1	0	0	3	7	1	8	54	38
	Salemata	28	1	0	0	1	26	0	4	50	46
	Kedougou	18	1	0	0	3	4	10	6	28	67
	Velingara	8	2	0	1	3	2	0	31	50	19
	Kolda	22	0	0	0	7	6	9	0	45	55

Genotypic Prevalence of kdr Mutations According to the Mosquito Phenotypic Status (alive vs dead)

The genotyping of the *An. gambiae* s.l. specimen collected from breeding sites from 12 sentinel districts, revealed the presence of both *kdr* mutations among dead and surviving (alive) specimen after exposure to insecticides (Table 17). However, no significant difference was observed in genotypic prevalence of the *kdr* mutations between the surviving and dead mosquitoes. Therefore, additional studies are needed to further assess the involvement of other potential resistance mechanisms in phenotypic resistant of *An. gambiae* s.l. populations.

Kdr Mutation Genotypic Prevalence by Species

The molecular identification of the specimens of the *An. gambiae* s.l. exposed to insecticides revealed the presence of both mutations, *kdr*-west and *kdr*-east, in all three species of the *An. gambiae* complex identified as *An. arabiensis*, *An. gambiae,* and *An. coluzzii* (Table 18). Of these, *An. arabiensis* had the highest prevalence of resistant homozygous (RR) and heterozygous (RS) genotypes for both *kdr* mutations, particularly in the urban districts of Pikine and Diamniadio, near Dakar. Nevertheless, in the southern part of the country (Sudanese and Sudano-Guinean zones), *An. gambiae* had the highest prevalence of homozygote RR.

TABLE 17: GENOTYPIC PREVALENCE OF *KDR*-WEST AND *KDR*-EAST MUTATIONS ACCORDING TO THE PHENOTYPIC STATUS OF *AN. GAMBIAE* S.L. FEMALES AFTER BEING EXPOSED TO INSECTICIDES

Geographical zone	Sentinel Districts	Status	Genotype									
			Kdr-w				P-value	*Kdr*-e				P-value
			N	SS	RS	RR		N	SS	RS	RR	
Sahelo-Sudanese	Pikine	Dead	13	0	0	13	1	6	0	0	6	1
		Alive	14	0	0	14		11	0	0	11	
	Diamnadio	Dead	8	0	2	6	*0.95*	15	0	0	15	1
		Alive	10	0	0	10		13	0	0	13	
Sudano-Sahelian	Diofor	Dead	14	7	1	6	0.32	14	6	3	5	0.375
		Alive	14	3	1	10		14	3	2	9	
	Ndoffane	Dead	7	4	1	2	0.826	14	5	0	9	1
		Alive	13	6	1	6		15	5	1	9	
	Nioro	Dead	26	20	0	6	0.283	28	17	1	10	1
		Alive	2	0	0	2		2	1	0	1	
	Koungheul	Dead	14	13	0	1	1	14	10	0	4	1
		Alive	14	13	1	0		14	11	0	3	
Sudanese	Makacolibantang	Dead	14	8	5	1	0.539	15	12	3	0	1
		Alive	15	5	9	1		15	11	3	1	
Sudano-Guinean	Saraya	Dead	8	3	0	5	0.765	5	4	0	1	0.007
		Alive	14	3	1	10		8	0	1	7	
	Salemata	Dead	9	1	0	8	0.31	9	1	0	8	0.548
		Alive	20	0	0	20		19	0	1	18	
	Kedougou	Dead	8	3	2	3	0.827	14	4	1	9	0.66
		Alive	9	2	2	5		11	1	1	9	
	Velingara	Dead	10	2	0	8	0.777	5	3	0	2	1
		Alive	9	2	1	6		4	2	1	1	
	Kolda	Dead	8	1	0	7	1	11	1	0	10	0.423
		Alive	11	1	0	10		5	0	0	5	

Note: N = Number tested; RR, RS, and SS represent the different genotypes with R corresponding to the resistant mutant allele (either for the *kdr*-west or kdr-east) and S to the susceptible wild type allele.

TABLE 18: GENOTYPIC PREVALENCE OF THE *KDR*-WEST AND *KDR*-EAST MUTATIONS BY SPECIES AND GEOGRAPHIC AREA

Geographical zine	Sentinel Districts	Species	Genotypes									
			Kdr-w				*P-value*	*Kdr*-e				*P-value*
			N	SS	RS	RR		N	SS	RS	RR	
Sahelo-Sudanese	Pikine	*An. arabiensis*	**27**	0	0	27	NS	**17**	0	0	17	NS
	Diamnadio	*An. arabiensis*	**18**	0	2	16	NS	**28**	0	0	28	NS
Sudano-Sahelian	Diofor	*An. arabiensis*	**28**	10	2	16	NS	**28**	9	5	14	NS
	Ndoffane	*An. arabiensis*	**20**	10	2	8	NS	**29**	10	1	18	NS
	Nioro	*An. arabiensis*	**26**	19	0	7	NS	**28**	16	1	11	NS
		An. gambiae	**1**	0	0	1		**1**	1	0	0	
	Koungheul	*An. arabiensis*	**27**	25	1	1	NS	**27**	20	0	7	NS
Sudanese	Makacolibantang	*An. arabiensis*	**29**	13	14	2	NS	**30**	23	6	1	NS
Sudano-Guinean	Saraya	*An. arabiensis*	**3**	2	0	1	0.326	**5**	4	1	0	0.0012
		An. gambiae	**15**	3	1	11		**7**	0	0	7	
	Salemata	*An. arabiensis*	**1**	1	0	0	0.034	**1**	1	0	0	0.071
		An. gambiae	**28**	0	0	28		**27**	0	1	26	
	Kedougou	*An. arabiensis*	**14**	5	4	5	0.276	**23**	5	2	16	1
		An. coluzzii	**3**	0	0	3		**2**	0	0	2	
	Velingara	*An. arabiensis*	**15**	4	1	10	0.624	**9**	5	1	3	1
		An. gambiae	**4**	0	0	4		**0**	0	0	0	
	Kolda	*An. arabiensis*	**6**	1	0	5	NA	**10**	1	0	9	1
		An. coluzzii	**0**	0	0	0		**2**	0	0	2	
		An. gambiae	**13**	1	0	12		**4**	0	0	4	

Note: N = Number tested; RR, RS, and SS represent the different genotypes with R corresponding to the resistant mutant allele (either for the Vgsc-1014F or Vgsc-1014S) and S to the susceptible wild allele Vgsc-1014L, NA = Not Applicable, NS = Not Significant

3.3.7 ACE 1^R MUTATION

The investigation of the Ace1^R mutation (G119S) revealed the exclusive presence of the wild-type (susceptible) allele in almost all the sentinel districts, excepted in the southern part of the country, where two homozygous RR specimens (Salemata) and five heterozygotes RS (Salemata: 4; Saraya: 1) were found (Figure 29 and Table 19). The *Ace*1^R mutation was found only in *An. gambiae* s.l. where it was present in both surviving and dead specimen post exposure to insecticides (Tables 20 and 21).

FIGURE 29: SPATIAL DISTRIBUTION AND PREVALENCE OF THE ACE 1^R MUTATION IN *AN. GAMBIAE* S.L.

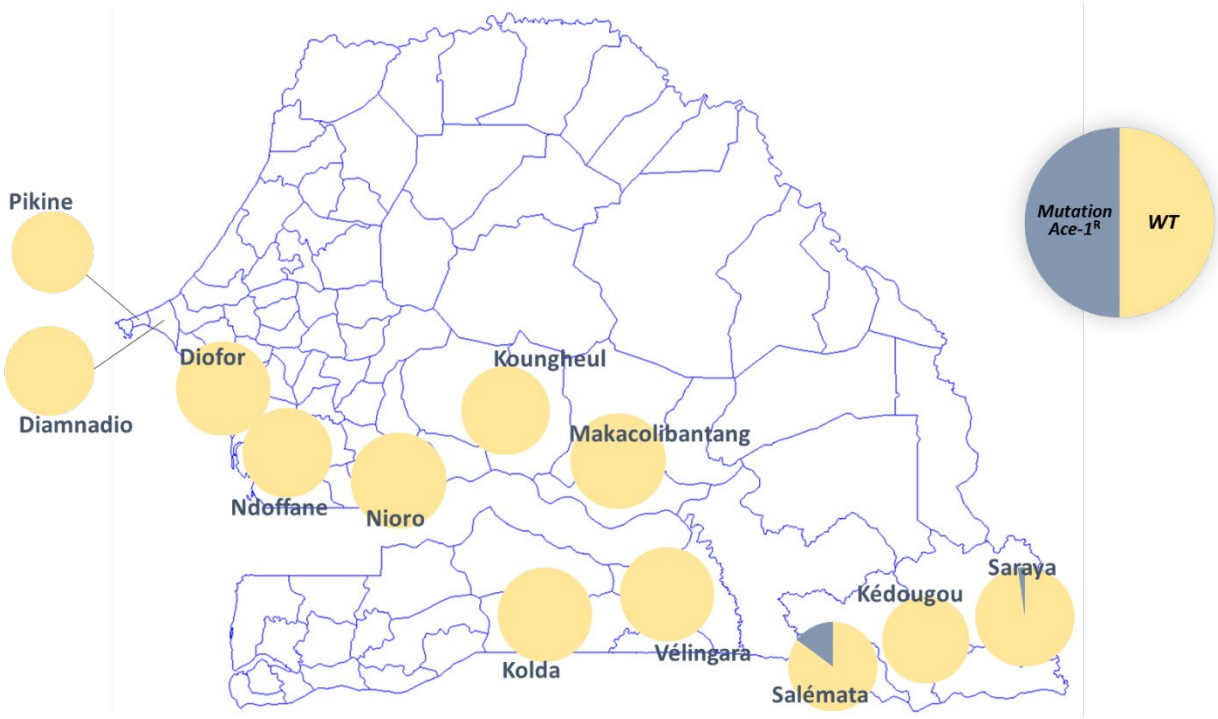


TABLE 19: GENOTYPIC PREVALENCE OF THE *ACE-1* MUTATION IN *AN. GAMBIAE* S.L. POPULATIONS ACCORDING TO THE DISTRICT AND GEOGRAPHICAL AREA

Geographical zone	Sentinel Districts	N	Genotypes			Allelic frequencies (%)	
			SS	RS	RR	S	R
Sahelo-Sudanese	Pikine	30	30	0	0	100	0
	Diamnadio	27	27	0	0	100	0
Sudano-Sahelian	Diofior	30	30	0	0	100	0
	Ndoffane	28	28	0	0	100	0
	Nioro	28	28	0	0	100	0
	Koungheul	28	28	0	0	100	0
Sudanese	Makacolibantang	30	30	0	0	100	0
Sudano-Guinean	Saraya	22	21	1	0	97.73	2.27
	Salemata	27	21	4	2	85.19	14.81
	Kedougou	28	28	0	0	100	0
	Velingara	27	27	0	0	100	0
	Kolda	25	25	0	0	100	0

Note: N= Number tested; RR, RS and SS represent the different genotypes with R corresponding to the resistant mutant allele (G119S) and S to the susceptible wild allele

TABLE 20: GENOTYPIC PREVALENCE OF THE ACE 1^R MUTATION ACCORDING TO THE PHENOTYPIC STATUS OF *AN. GAMBIAE* S.L. FEMALES AFTER THEIR EXPOSURE TO INSECTICIDES

Sentinel Districts	Status	N	*Ace 1* genotypes		
			SS	RS	RR
Pikine	Dead	22	22	0	0
	Alive	8	8	0	0
Diamnadio	Dead	14	14	0	0
	Alive	13	13	0	0

Diofor	Dead	30	30	0	0
	Alive	0	0	0	0
Ndoffane	Dead	27	27	0	0
	Alive	1	1	0	0
Nioro	Dead	26	26	0	0
	Alive	2	2	0	0
Koungheul	Dead	15	15	0	0
	Alive	13	13	0	0
Makacolibantang	Dead	30	30	0	0
	Alive	0	0	0	0
Saraya	Dead	11	11	0	0
	Alive	11	10	1	0
Salemata	Dead	8	6	0	2
	Alive	19	15	4	0
Kedougou	Dead	14	14	0	0
	Alive	14	14	0	0
Velingara	Dead	13	13	0	0
	Alive	14	14	0	0
Kolda	Dead	23	23	0	0
	Alive	2	2	0	0

TABLE 21: GENOTYPIC PREVALENCE OF THE ACE 1^R MUTATION BY SPECIES, DISTRICT, AND GEOGRAPHICAL AREA

Geographical zone	Sentinel Districts	Species	N	*Ace-1* genotypes		
				SS	RS	RR
Sahelo-Sudanese	Pikine	*An. arabiensis*	29	29	0	0
	Diamnadio	*An. arabiensis*	27	27	0	0
Sudano-Sahelian	Diofor	*An. arabiensis*	30	30	0	0
	Ndoffane	*An. arabiensis*	27	27	0	0
		An. gambiae	1	1	0	0
	Nioro	*An. arabiensis*	25	25	0	0
		An. gambiae	2	2	0	0
	Koungheul	*An. arabiensis*	27	27	0	0
Sudanese	Makacolibantang	*An. arabiensis*	30	30	0	0
Sudano-Guinean	Saraya	*An. arabiensis*	5	5	0	0
		An. gambiae	16	15	1	0
	Salemata	*An. arabiensis*	1	1	0	0
		An. gambiae	25	19	4	2
	Kedougou	*An. arabiensis*	26	26	0	0
		An. gambiae	2	2	0	0
	Velingara	*An. arabiensis*	25	25	0	0
		An. coluzzii	1	1	0	0
		An. gambiae	1	1	0	0
	Kolda	*An. arabiensis*	18	18	0	0

4. CONCLUSION

In all the sentinel districts surveyed, *An. arabiensis* (*An. gambiae* s.l.) remains the predominant species of the anopheline fauna. The highest densities of *An. funestus* s.l. were recorded in Nioro and Ndoffane. Moreover in 2019, the presence of *An. pharoensis*, and *An. funestus* s.l. was recorded in the Sahelian region of the country, but were not observed in that zone during the 2018 entomological monitoring activities.

The biting rates of *An. gambiae* s.l. were high during the rainy season (September-October), with the highest host-seeking female densities recorded in the Sudanese and Sudano-Guinean zones. Both *An. gambiae* s.l. and *An. funestus* s.l. were more active between 02 a.m. and 05 a.m. of the night. Although there was no significant inter-zone variations, a significantly larger proportion of females were caught indoors through HLCs (endophagic) in each zone. Conversely, female *An. funestus s.l.*, for which the highest biting rates were recorded in the Sudano-Sahelian zone, displayed an overall outdoor biting (exophagic) tendency, except in the district of Nioro. The vector behavior and periodical density will support the type and timing of vector control measures to be put in place in the country, such as IRS.

High IDRs were also recorded for *An. gambiae* s.l. during the rainy season. However, female *An. gambiae* s.l. remain endophagic and endophilic in the Sahelian zone, but endophagic and exophilic in the Sudano-Guinean zone. Additionally, the biting and resting behaviors of *An. gambiae* s.l. have not changed in the Sudano-Guinean zone per earlier data. In contrast, *An. gambiae* s.l. of the Sahelian zone have likely changed their behavior from exophilic tendency to endophagic. In Nioro and Ndoffane, where larger numbers of *An. funestus* s.l. were collected, *An. funestus* s.l. displayed a clear endophilic tendency.

High biting and anthropophilic rates of *An. gambiae* s.l. were observed in the Sudano-Guinean zone, where malaria transmission remains the highest of the geographical zones. In Richard Toll district, in the Sahelian zone, both *An. funestus* and *An. gambiae* s.l. carried malaria parasites and were therefore involved in malaria transmission. The low entomological inoculation rate of *An. gambiae* s.l. in the Sahelian zone could be explained both by their low biting rates and their zoophagic tendency. Compared to the Sudano-Guinean area, the involvement of *An. funestus* s.l. in malaria transmission in the Sahelian zone could be linked to their high biting and mean parity rates, as well as to their anthropophilic tendency.

Resistance to all pyrethroids tested was observed in the *An. gambiae* s.l. populations in all geographical zones, though an increase in mortality was noted when the mosquitoes were pre-exposed with association to PBO. The vectors remained susceptible to pirimiphos-methyl and clothianidin across all the surveyed geographical areas of the country. This trend is important as Senegal is resuming the implementation of IRS for malaria vector control in 2020.

Furthermore, susceptibility to chlorfenapyr was observed in a majority of sites and geographical zones except in Diamniadio. Therefore, in addition to the PBO-incorporated ITNs, chlorfenapyr-based ITNs could be targeted for distribution in specific areas of higher malaria transmission.

5. REFERENCES

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6. ANNEXES

ANNEX A: ANOPHELES SPECIES COMPOSITION AND PROPORTION BY GEOGRAPHICAL AREA

	Eco geographical zones				
Species	**Sahelian**	**Sahelo Sudanese**	**Sudano Sahelian**	**Sudanese**	**Sudano Guinean**
An. gambiae s.l.	324 (57.86%)	2 054 (90.41%)	6 180 (63.42%)	4 274 (99.65%)	8 394 (98.96%)
An. funestus s.l.	142 (25.36%)	7 (0.31%)	3 393 (34.82%)	0 (0%)	35 (0.41%)
An. pharoensis	43 (7.68%)	44 (1.95%)	29 (0.30%)	2 (0.05%)	12 (0.14%)
An. squamosus	0 (0%)	0 (0%)	0 (0%)	2 (0.05%)	0 (0%)
An. rufipes	24 (4.29%)	166 (7.34%)	132 (1.35%)	3 (0.07%)	1 (0.01%)
An. coustani	9 (1.61%)	0 (0%)	5 (0.05%)	7 (0.16%)	5 (0.06%)
An. welcomei	0 (0%)	0 (0%)	5 (0.05%)	0 (0%)	1 (0.01%)
An. nili	0 (0%)	0 (0%)	0 (0%)	1 (0.02%)	34 (0.40%)
An. flavicosta	18 (3.21%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	**560 (100%)**	**2 262 (100%)**	**9 744 (100%)**	**4 289(100%)**	**8 482(100%)**

ANNEX B: HUMAN BITING RATE (HBR), ENDOPHAGIC RATES (ER), INDOOR RESTING DENSITIES (IRD) AND PARITY RATE (PR) OF *AN. GAMBIAE* S.L. FEMALES BY SITES AND GEOGRAPHIC AREA

	Districts	HLC	Man/Night	HBR	Indoor catches	Outdoor catches	Endophagic rates	Total dissected	Parous	Parity rate (%)	PSC	Number of rooms	Resting densities
Sahelian	Richard Toll	30	72	0.42	18	12	0.60	30	24	80.00	18	60	0.30
	Podor	77	72	1.07	36	41	0.47	78	60	76.92	199	60	3.32
Total		**107**	**72**	**0.00**	**54**	**53**	**0.50**	**108**	**84**	**77.78**	**217**	**60**	**3.62**
Sahelo-Sudanese	Matam	51	72	0.71	28	23	0.55	51	39	76.47	1268	60	21.13
	Kanel	5	72	0.07	4	1	0.80	5	1	20.00	35	60	0.58
	Bakel	32	72	0.44	20	12	0.63	32	21	65.63	57	60	0.95
	Ranerou	32	72	0.44	21	11	0.66	32	28	87.50	75	60	1.25
	Linguere	38	72	0.53	22	16	0.58	33	22	66.67	170	60	2.83
	Pikine*	-	-	-	-	-	-	-	-	-	39	30	1.30
	Tivaoune	17	96	0.18	9	8	0.53	5	3	60	212	80	2.65
	Thies#	-	-	-	-	-	-	-	-	-	1	40	0.03
Total		**175**	**456**	**0.38**	**104**	**71**	**0.59**	**158**	**114**	**72.15**	**1857**	**450**	**4.13**
Sudano-Sahelian	Diofior	715	48	14.90	424	291	0.59	174	42	24.14	367	40	9.18
	Niakhar	156	48	3.25	93	63	0.60	73	40	54.79	2078	40	51.95
	Koungheul	26	144	0.18	16	10	0.62	8	5	62.50	75	120	0.63
	Nioro	70	144	0.49	27	43	0.39	54	21	38.89	989	120	8.24
	Ndoffane	281	144	1.95	99	182	0.35	218	36	16.51	1423	120	11.86
Total		**1248**	**528**	**2.36**	**659**	**589**	**0.53**	**527**	**144**	**27.32**	**4932**	**440**	**11.21**
Sudanese	Makacolibantang	141	72	1.96	69	72	0.49	90	58	64.44	122	80	1.53
	Tambacounda	2256	120	18.80	1293	963	0.57	236	160	67.80	88	100	0.88
	Dianke Makha	1540	72	21.39	742	798	0.48	208	160	76.92	127	60	2.12
Total		**3937**	**264**	**14.91**	**2104**	**1833**	**0.53**	**534**	**378**	**70.79**	**337**	**240**	**1.40**
Sudano-Guinean	Kedougou	3089	144	21.45	1897	1192	0.61	879	486	55.29	48	120	0.40
	Saraya	891	48	18.56	349	542	0.39	411	346	84.18	11	40	0.28
	Salemata	450	48	9.38	226	224	0.50	375	278	74.13	24	40	0.60
	Velingara	990	120	8.25	450	540	0.45	592	398	67.23	124	100	1.24
	Kolda	113	72	1.57	71	42	0.63	103	92	89.32	41	60	0.68
	Oussouye	1024	72	14.22	431	593	0.42	427	105	24.59	22	60	0.37
Total		**6557**	**504**	**13.01**	**3424**	**3133**	**0.52**	**2787**	**1705**	**61.18**	**270**	**420**	**0.64**

Note: HLC: human landing catch; PSC: pyrethrum spray collection
*: collections done by CDC light trap

ANNEX C: HUMAN BITING RATES (HBR), ENDOPHAGIC RATES (ER), INDOOR RESTING DENSITIES (IRD) ET PARITY RATE (PR) OF *AN. FUNESTUS* S.L. FEMALES BY SITES AND GEOGRAPHIC AREA

Zone	District	Total caught by HLC	Man/Night	Biting densities	Indoor catches	Outdoor catches	Endophagic rates	Total dissected	Parous	Parity rate (%)	Total collected by PSC	Number of rooms	Resting densities
Sahelian	Richard Toll	54	48	1.13	20	34	0.37	54	45	83.33	73	60	1.22
	Podor	3	48	0.06	1	2	0.33	3	3	100.00	4	60	0.07
Total		**57**	**96**	**0.6**	**21**	**36**	**0.37**	**57**	**48**	**84.21**	**77**	**120**	**0.64**
Sahelo-Sudanese	Ranerou	0	48	0.00	0	0	0.00	0	0	0.00	7	60	0.12
Total		**0**	**48**	**0.00**	**0**	**0**	**0.00**	**0**	**0**	**0.00**	**7**	**60**	**0.12**
Sudano-Sahelian	Nioro	265	144	1.84	145	120	0.55	211	85	40.28	1574	120	13.12
	Ndoffane	774	144	5.38	284	490	0.37	632	233	36.87	780	120	6.50
Total		**1039**	**288**	**7.22**	**429**	**610**	**0.92**	**843**	**318**	**77.15**	**2354**	**240**	**9.81**
Sudano-Guinean	Kedougou	0	144	0	0	0	0	0	0	0	1	120	0.01
	Saraya	5	48	0.10	1	4	0.20	3	3	100	1	40	0.03
	Velingara	0	120	0.00	0	0	0.00	0	0	0.00	5	100	0.05
	Kolda	0	72	0.00	0	0	0.00	0	0	0.00	23	60	0.38
Total		**5**	**384**	**0.01**	**1**	**4**	**0.2**	**3**	**3**	**100**	**30**	**320**	**0.09**

ANNEX D: ABDOMINAL STATUS OF INDOOR RESTING *AN. GAMBIAE* S.L. FEMALES BY SITES AND GEOGRAPHICAL AREA

Geographical zone	District	Total	Unfed	Blood-fed	Half-gravid	Gravid
Sahelian	Richard Toll	18	0%	15 (83.33%)	1 (5.56%)	2 (11.11%)
	Podor	199	4 (2.01%)	145 (72.86%)	1 (0.50%)	49 (24.62%)
Total		**217**	**4 (1.84%)**	**160 (73.73%)**	**2 (0.92%)**	**51 (23.50%)**
Sahelo-Sudanese	Matam	1268	2 (0.16%)	947 (74.68%)	0%	319 (25.16%)
	Kanel	35	0%	25 (71.43%)	1 (2.86%)	9 (25.71%)
	Bakel	57	0%	46 (80.70%)	1 (1.75%)	10 (17.50%)
	Ranerou	75	0%	61 (81.33%)	1 (1.33%)	13 (17.33%)
	Linguere	170	1 (0.59%)	133 (78.24%)	3 (1.76%)	33 (19.41%)
	Pikine	39	4 (10.26%)	10 (25.64%)	12 (30.77%)	13 (33.33%)
	Tivaoune	212	22 (10.38%)	68 (32.08%)	60 (28.30%)	62 (29.25%)
	Thies	1	0%	0%	1 (100%)	0%
Total		**1857**	**29 (1.56%)**	**1290 (69.47%)**	**79 (4.25%)**	**459 (24.72%)**
Sudaneo-Sahelian	Diofior	367	12 (3.27%)	184 (50.00%)	17 (5.00%)	154 (42.00%)
	Niakhar	2078	209 (10.06%)	1239 (59.64%)	0%	630 (30.32%)
	Koungheul	75	0%	25 (33.33%)	21 (28.00%)	29 (38.67%)
	Nioro	989	112 (11.32%)	469 (47.42%)	137 (13.85%)	271 (27.40%)
	Ndoffane	1423	45 (3.16%)	865 (60.79%)	315 (22.14%)	198 (13.91%)
Total		**4932**	**378 (7.66%)**	**2782 (56.41%)**	**490 (9.94%)**	**1282 (25.99%)**
Sudanese	Makacolibantang	122	0%	39 (31.97%)	53 (43.44%)	30 (24.59%)
	Tambacounda	88	11 (12.50%)	41 (46.59%)	14 (15.91%)	22 (25.00%)
	Dianke Makha	127	15 (11.81%)	46 (36.22%)	24 (18.90%)	42 (33.07%)
Total		**337**	**26 (7.72%)**	**126 (37.39%)**	**91 (27.00%)**	**94 (27.89%)**
Sudano-Guinean	Kedougou	48	7 (14.58%)	35 (72.92%)	2 (4.17%)	4 (8.33%)
	Saraya	11	0%	9 (81.82%)	0%	2 (18.18%)
	Salemata	24	1 (4.17%)	18 (75.00%)	0%	5 (20.83%)
	Velingara	124	8 (6.41%)	73 (58.87%)	3 (2.42%)	40 (32.26%)
	Kolda	41	1 (2.44%)	23 (56.10%)	1 (2.44%)	16 (39.02%)
	Oussouye	22	1 (4.55%)	19 (86.36%)	1 (4.55%)	1 (4.55%)
Total		**270**	**18 (6.67%)**	**177 (65.56%)**	**7 (2.59%)**	**68 (25.19%)**

ANNEX E: HUMAN BITING RATES (HBR), ENDOPHAGIC RATES (ER), INDOOR RESTING DENSITIES (IRD) AND PARITY RATE (PR) OF *AN. FUNESTUS* S.L. FEMALES IN THE SENTINEL DISTRICTS BY SITE, GEOGRAPHIC AREA AND SEASON

		Total caught by HLC		HBRs		Endophagic rates		Parity rate		Total collected by PSC		Resting densities	
Geographical zone	District	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS
Sahelian	Richard Toll	28	26	1.17	1.08	0.36	0.38	85.71	80.77	13	60	0.33	3.00
	Podor	3	0	0.13	0.00	0.33	0.00	100.00	0.00	4	0	0.10	0.00
Total		**31**	**26**	0.65	0.54	0.35	0.38	87.10	80.77	**17**	**60**	0.21	1.50
Sahelo-Sudanese	Ranerou	0	0	0.00	0.00	0.00	0.00	0.00	0.00	7	0	0.18	0.00
Total		**0**	**0**	0.00	0.00	0.00	0.00	0.00	0.00	**7**	**0**	0.18	0.00
Sudano-Sahelian	Nioro	112	153	2.33	1.59	0.51	0.58	48.89	33.88	521	1053	13.03	13.16
	Ndoffane	345	429	7.19	4.47	0.34	0.39	40.87	34.21	308	472	7.70	5.90
Total		**457**	**582**	4.76	3.03	0.38	0.44	42.98	34.13	**829**	**1525**	10.36	9.53
Sudano-Guinean	Kedougou	0	0	0.00	0.00	0.00	0.00	0.00	0.00	1	0	0.03	0.00
	Saraya	5	0	0.21	0.00	0.20	0.00	100	0.00	1	0	0.05	0.00
	Velingara	0	0	0.00	0.00	0.00	0.00	0.00	0.00	2	3	0.03	0.08
	Kolda	0	0	0.00	0.00	0.00	0.00	0.00	0.00	14	9	0.35	0.45
Total		**5**	**0**	0.04	0.00	0.20	0.00	100	0.00	**18**	**12**	0.11	0.08

Note: RS = rainy season; DS = dry season

ANNEX F: ABDOMINAL STATUS OF INDOOR RESTING *AN. FUNESTUS* S.L. FEMALES BY GEOGRAPHICAL AREA, SITES, AND SEASON

		Total		Unfed		Blood-fed		Half-gravid		Gravid	
Zone	**District**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**
Sahelian	Richard Toll	13	60	0%	1 (1.67%)	10 (76.92%)	44 (73.33%)	2 (15.38%)	3 (5.00%)	1 (7.69%)	12 (20.00%)
	Podor	4	0	0%	0%	2 (50.00%)	0%	1 (25.00%)	0%	1 (25.00%)	0%
	Total	17	60	0%	1 (1.67%)	12 (70.59%)	44 (73.33%)	3 (17.65%)	3 (5.00%)	2 (11.76%)	12 (20.00%)
Sahelo-Sudanese	Ranerou	7	0	1 (14.29%)	0%	2 (28.57%)	0%	1 (14.29%)	0%	3 (42.86%)	0%
	Total	7	0	1 (14.29%)	0%	2 (28.57%)	0%	1 (14.29%)	0%	3 (42.86%)	0%
Sudano-Sahelian	Nioro	521	1053	48 (9.21%)	88 (8.36%)	308 (59.12%)	583 (55.37%)	64 (12.28%)	152 (14.43%)	101 (19.39%)	230 (21.84%)
	Ndoffane	308	472	11 (3.57%)	51 (10.81%)	177 (57.47	279 (59.11%)	77 (25.00%)	53 (11.23%)	43 (13.96%)	89 (18.86%)
	Total	829	1525	59 (7.12%)	139 (9.11%)	485 (58.50%)	862 (56.52%)	141 (17.01%)	205 (13.44%)	144 (17.37%)	319 (20.92%)
Sudano-Guinean	Kedougou	1	0	0%	0%	1 (100%)	0%	0%	0%	0%	0%
	Saraya	1	0	0%	0%	0%	0%	0%	0%	1 (100%)	0%
	Velingara	2	3	0%	0%	2 (100%)	3 (100%)	0%	0%	0%	0%
	Kolda	14	9	1 (7.14%)	3 (33.33%)	12 (85.72%)	6 (66.67%)	1 (7.14%)	0%	0%	0%
	Total	18	12	1 (5.56%)	3 (25.00%)	15 (83.33%)	9 (75.00%)	1 (5.56%)	0%	1 (5.56%)	0%

Note: RS = rainy season; DS = dry season

ANNEX G: HUMAN BITING RATES (HBR), ENDOPHAGIC RATES (ER), INDOOR RESTING DENSITIES (IRD) AND PARITY RATE (PR) OF *AN. GAMBIAE* S.L. FEMALE BY THE SENTINEL DISTRICTS, SITE AND SEASON

	Total caught by HLC		Number Man/Night		HBR		Indoor catches		Outdoor catches		Endophagic rates		Total dissected		Parous		Parity rate		Total collected by PSC		Number of rooms		Resting densities	
District	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**
Richard Toll	24	6	24	24	1.00	0.25	15	3	9	3	0.63	0.5	24	6	20	4	83.333	66.667	12	0	40	20	0.3	0
Podor	46	31	24	24	1.92	1.29	22	14	24	17	0.48	0.452	46	32	34	26	73.913	81.25	36	155	40	20	0.9	7.75
Total	**70**	**37**	**48**	**48**	**1.46**	**0.77**	**37**	**17**	**33**	**20**	**0.53**	**0.459**	**70**	**38**	**54**	**30**	**77.143**	**78.947**	**48**	**155**	**80**	**40**	**0.6**	**3.88**
Linguere	11	27	24	24	0.46	1.13	6	16	5	11	0.55	0.593	11	22	7	15	63.636	68.182	20	149	40	20	0.5	7.45
Matam	21	30	24	24	0.88	1.25	9	19	12	11	0.43	0.633	21	30	17	22	80.952	73.333	1162	104	40	20	29.05	5.2
Kanel	5	0	24	24	0.21	0.00	4	0	1	0	0.8	0.00	5	0	1	0	20.00	0.00	11	22	40	20	0.275	1.1
Bakel	14	18	24	24	0.58	0.75	7	13	7	5	0.5	0.722	14	18	4	17	28.571	94.444	17	39	40	20	0.425	1.95
Ranerou	14	18	24	24	0.58	0.75	8	13	6	5	0.57	0.722	14	18	10	18	71.429	100	19	57	40	20	0.475	2.85
Pikine*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	4	20	10	1.75	0.40
Tivaoune	17	0	48	48	0.40	0.00	9	0	8	0	0.5	0.00	5	0	3	0	60.00	0.00	211	1	80	80	2.63	0.01
Thies#	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	20	20	0.05	0.00
Total	**82**	**93**	**168**	**168**	**0.4881**	**0.5536**	**43**	**61**	**39**	**32**	**0.52**	**0.656**	**70**	**88**	**42**	**72**	**60**	**81.818**	**1476**	**376**	**320**	**210**	**4.613**	**1.79**
Dioffior	715	-	48	-	14.90	nd	424	-	291	-	0.59	-	174	-	42	-	24.14	-	367	-	40	-	9.18	-
Niakhar	156	0	48	0	3.25	0.00	93	0	63	0	0.60	0.00	73	0	40	0	54.79	0.00	2078	0	40	0	52.00	0.00
Koungheul	24	2	48	96	0.50	0.02	15	1	9	1	0.63	0.50	6	2	3	2	50.00	100	61	14	40	80	1.53	0.18
Nioro	50	20	48	96	1.04	0.21	20	7	30	13	0.40	0.35	36	18	16	5	44.444	27.778	791	198	40	80	19.78	2.48
Ndoffane	92	189	48	96	1.92	1.97	26	73	66	116	0.28	0.39	65	153	12	24	18.462	15.686	718	705	40	80	17.95	8.81
Total	**1037**	**211**	**240**	**288**	**4.3208**	**0.7326**	**578**	**81**	**459**	**130**	**0.56**	**0.384**	**354**	**173**	**113**	**31**	**31.921**	**17.919**	**4015**	**917**	**200**	**240**	**20.08**	**3.82**
Makacolibantang	136	5	48	24	2.8333	0.21	69	0	67	5	0.51	0.00	87	3	55	3	63.22	100	115	7	40	40	2.88	0.18
Tambacounda	2256	0	48	72	47.00	0.00	1293	0	963	0	0.57	0.00	236	0	160	0	67.80	0.00	88	0	40	60	2.20	0.00
Dianke Makha	1540	0	48	24	32.083	0.00	742	0	798	0	0.48	0.00	208	0	160	0	76.92	0.00	127	0	40	20	3.18	0.00
Total	**3932**	**5**	**144**	**120**	**27.306**	**0.0417**	**2104**	**0**	**1828**	**5**	**0.54**	**0**	**531**	**3**	**375**	**3**	**70.621**	**100**	**330**	**7**	**120**	**120**	**2.75**	**0.06**
Kedougou	3067	22	48	96	63.90	0.23	1885	12	1182	10	0.61	0.55	858	21	465	21	54.20	100.00	39	9	40	80	0.98	0.11
Velingara	975	15	72	48	13.542	0.31	442	8	533	7	0.45	0.53	577	15	383	15	66.38	100	109	15	60	40	1.82	0.38
Salemata	438	12	24	24	18.25	0.50	216	10	222	2	0.49	0.83	363	12	266	12	73.28	100.00	24	0	20	20	1.20	0.00
Saraya	884	7	24	24	36.833	0.2917	343	6	541	1	0.39	0.86	407	4	342	4	84.03	100.00	11	0	20	20	0.55	0.00
Kolda	110	3	48	24	2.29	0.13	70	1	40	2	0.64	0.33	100	3	89	3	89.00	100	23	18	40	20	0.58	0.90
Oussouye	1024	0	48	24	21.33	0.00	431	0	593	0	0.42	0.00	427	0	105	0	24.59	0.00	22	0	40	20	0.55	0.00
Total	**6498**	**59**	**264**	**240**	**24.614**	**0.2458**	**3387**	**37**	**3111**	**22**	**0.52**	**0.627**	**2732**	**55**	**1650**	**55**	**60.395**	**100**	**228**	**42**	**220**	**200**	**1.036**	**0.21**

Note: RS = rainy season; DS = dry season *collections done by CDC light trap #: No catch planned in this district

ANNEX H: HUMAN BITING RATES (HBR), ENDOPHAGIC RATES (ER), INDOOR RESTING DENSITIES (IRD) ET PARITY RATE (PR) OF *AN. FUNESTUS* S.L. FEMALES BY GEOGRAPHIC AREA, DISTRICTS, SITES AND SEASON

		Total caught by HLC		Man/Night		HBR		Indoor catches		Outdoor catches		Endophagic rates		Total dissected		Parous		Parity rate		Total collected by PSC		Number of rooms		Resting densities	
Geographical zone	**District**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**
Sahelian	Richard Toll	28	26	24	24	1.17	1.08	10	10	18	16	0.36	0.38	28	26	24	21	85.71	80.77	13	60	40	20	0.33	3.00
	Podor	3	0	24	24	0.13	0.00	1	0	2	0	0.33	0.00	3	0	3	0	100.00	0.00	4	0	40	20	0.10	0.00
Total		**31**	**26**	**48**	**48**	0.65	0.54	**11**	**10**	**20**	**16**	0.35	0.38	**31**	**26**	**27**	**21**	87.10	80.77	**17**	**60**	**80**	**40**	0.21	1.50
Sahelo-Sudanese	Ranerou	0	0	24	24	0.00	0.00	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00	7	0	40	20	0.18	0.00
Total		**0**	**0**	**24**	**24**	0.00	0.00	**0**	**0**	**0**	**0**	0.00	0.00	**0**	**0**	**0**	**0**	0.00	0.00	**7**	**0**	**40**	**20**	0.18	0.00
Sudano-Sahelian	Nioro	112	153	48	96	2.33	1.59	57	88	55	65	0.51	0.58	90	121	44	41	48.89	33.88	521	1053	40	80	13.03	13.16
	Ndoffane	345	429	48	96	7.19	4.47	117	167	228	262	0.34	0.39	252	380	103	130	40.87	34.21	308	472	40	80	7.70	5.90
Total		**457**	**582**	**96**	**192**	4.76	3.03	**174**	**255**	**283**	**327**	0.38	0.44	**342**	**501**	**147**	**171**	42.98	34.13	**829**	**1525**	**80**	**160**	10.36	9.53
Sudano-Guinean	Kedougou	0	0	48	96	0.00	0.00	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00	1	0	40	80	0.03	0.00
	Saraya	5	0	24	24	0.21	0.00	1	0	4	0	0.20	0.00	3	0	3	0	100	0.00	1	0	20	20	0.05	0.00
	Velingara	0	0	24	24	0.00	0.00	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00	2	3	60	40	0.03	0.08
	Kolda	0	0	24	24	0.00	0.00	0	0	0	0	0.00	0.00	0	0	0	0	0.00	0.00	14	9	40	20	0.35	0.45
Total		**5**	**0**	**120**	**168**	0.04	0.00	**1**	**0**	**4**	**0**	0.20	0.00	**3**	**0**	**3**	**0**	100	0.00	**18**	**12**	**160**	**160**	0.11	0.08

Note: RS = rainy season; DS = dry season

ANNEX I: SPECIES COMPOSITION OF THE ANOPHELINE FAUNA BY DISTRICTS, SITES, AND SEASON

District	Collected*		An. gambiae s.l.		An. funestus s.l.		An. pharoensis		An. squamosus		An. rufipes		An. ziemani		An. wellcomei		An.nili		An. flavicosta	
	RS	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**
Richard Toll	103	112	42 (40.78 %)	6 (5.36%)	41 (39.81 %)	86 (76.79%)	15 (14.56 %)	0%	0%	0%	2 (1.94%)	0%	1 (0.97%)	4 (3.57%)	0%	0%	0%	0%	0%	0%
Podor	131	218	90 (68.70 %)	186 (85.32 %)	7 (5.34%)	8 (3.67%)	25 (19.08 %)	3 (1.38%)	0%	0%	5 (3.82%)	17 (7.80%)	4 (3.05%)	0%	0%	0%	0%	0%	2 (1.53 %)	16 (7.34 %)
Total	234	330	132 (56.41 %)	192 (58.18 %)	48 (20.51 %)	94 (28.48%)	40 (17.09 %)	3 (0.91%)	0%	0%	7 (2.99%)	17 (5.15%)	5 (2.14%)	4 (1.21%)	0%	0%	0%	0%	2 (0.85 %)	16 (4.85 %)
Ranerou	40	87	34 (85.00 %)	75 (86.21 %)	0%	7 (8.05%)	4 (10.00 %)	0%	0%	0%	2 (5.00%)	5 (5.75%)	0%	0%	0%	0%	0%	0%	0%	0%
Linguere	34	176	32 (94.12 %)	176 (100%)	0%	0%	0%	0%	0%	0%	2 (5.88%)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Matam	1329	158	1187 (89.32 %)	134 (84.81 %)	0%	0%	35 (2.63%)	2 (1.27%)	0%	0%	107 (8.05%)	22 (13.92 %)	0%	0%	0%	0%	0%	0%	0%	0%
Kanel	27	13	18 (66.67 %)	12 (92.31 %)	0%	0%	1 (3.70%)	0%	0%	0%	8 (29.63 %)	1 (7.69%)	0%	0%	0%	0%	0%	0%	0%	0%
Bakel	43	66	32 (74.42 %)	57 (86.36 %)	0%	0%	1 (2.33%)	1 (1.52%)	0%	0%	10 (23.26 %)	8 (12.12 %)	0%	0%	0%	0%	0%	0%	0%	0%
Pikine	54	4	54 (100%)	4 (100%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tivaoune	229	1	228 (99.56 %)	1 (100%)	0%	0%	0%	0%	0%	0%	1 (0.44%)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Thies	1	0	1 (100%)	0%	0%	0 %	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	1757	505	1586 (90.27 %)	459 (90.89 %)	0%	7 (1.39%)	41 (2.33%)	3 (0.59%)	0%	0%	130 (7.40%)	36 (7.13%)	0%	0%	0%	0%	0%	0%	0%	0%
Dioffior	1084	-	1082 (99.81 %)	-	0%	-	2 (0.18%)	-	0%	-	0%	-	0%	-	0%	-	0%	-	0%	0%
Niakhar	2248	0	2234 (99.38 %)	0%	0%	0%	0%	0%	0%	0%	14 (0.62%)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Koungheul	92	19	85 (92.39 %)	16 (84.21 %)	0%	0%	7 (7.61%)	3 (15.79 %)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

District	Collected*		An. gambiae s.l.		An. funestus s.l.		An. pharoensis		An. squamosus		An. rufipes		An. ziemani		An. wellcomei		An.nili		An. flavicosta	
	RS	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**
Nioro	1504	1513	841(55.91%)	218 (14.41%)	633 (42.09%)	1206 (79.71%)	1 (0.07%)	15 (0.99%)	0%	0%	26 (1.73%)	70 (4.63%)	1 (0.07%)	4 (0.26%)	2 (0.13%)	0%	0%	0%	0%	0%
Ndoffane	1472	1812	810 (55.03%)	894 (49.34%)	653 (44.36%)	901 (49.72%)	0%	1 (0.06%)	0%	0%	6 (0.41%)	16 (0.88%)	0%	0%	3 (0.20%)	0%	0%	0%	0%	0%
Total	6400	3344	5052 (78.94%)	1128 (33.73%)	1286 (20.09%)	1107 (33.10%)	10 (0.16%)	19 (0.57%)	0%	0%	46 (0.72%)	86 (2.57%)	1 (0.02%)	4 (0.12%)	5 (0.08%)	0%	0%	0%	0%	0%
Makacoulibantang	252	12	251 (99.60%)	0%	0%	0%	1 (0.40%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tambacounda	2357	0	2344 (99.45%)	0%	0%	0%	2 (0.08%)	0%	2 (0.08%)	0%	2 (0.08%)	0%	0%	0%	0%	0%	7 (0.30%)	0%	0%	0%
Dianke Makha	1668	0	1667 (99.94%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1 (0.06%)	0%	0%	0%
Total	4277	12	4262 (99.65%)	%	%	%	1 (0.02%)	%	2 (0.05%)	%	2 (0.05%)	%	%	%	%	%	8 (0.19%)	%	%	%
Kedougou	3113	33	3106 (99.78%)	31 (93.94%)	1 (0.03%)	0%	1 (0.03%)	2 (6.06%)	0%	0%	0%	0%	0%	0%	0%	0%	5 (0.16%)	0%	0%	0%
Saraya	920	7	895 (97.28%)	7 (100%)	6 (0.65%)	0%	2 (0.22%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	17 (1.85%)	0%	0%	0%
Salemata	470	15	462 (98.30%)	12 (80%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8 (1.70%)	3 (20%)	0%	0%
Velingara	1089	35	1084 (99.54%)	30 (85.71%)	2 (0.18%)	3 (8.57%)	2 (0.18)	1 (2.86%)	0%	0%	0%	1 (2.86%)	0%	0%	0%	0%	3 (0.28%)	0%	0%	0%
Kolda	149	30	133 (89.26%)	21 (70.00%)	14 (9.39%)	9 (30.00%)	1 (0.67%)	0%	0%	0%	0%	0%	0%	0%	1 (0.67%)	0%	0%	0%	0%	0%
Oussouye	1048	0	1046 (99.81%)	0%	0%	0%	1 (0.10%)	0%	0%	0%	1 (0.10%)	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	6789	113	6726 (99.07%)	101 (89.38%)	23 (0.34%)	12 (10.62%)	7 (0.10%)	3 (2.65%)	0%	%	1 (0.01%)	1 (0.88%)	%	%	1 (0.01%)	%	33 (0.49%)	3 (2.65%)	%	%

Note: RS = rainy season; DS = dry season

***** = Specimen collected on human and by PSC, excepted for the district of Pikine where only PSC collection were carried out

ANNEX J-A: INSECTICIDE SUSCEPTIBILITY MONITORING AND INTENSITY OF RESISTANCE TO PYRETHROIDS

Locality	Permethrin			Deltamethrin			Alpha-cypermethrine			Bendiocarb		Pirimiphos-methyl		PBO +	Clothianidin	Chlofenapyr
	1X	5X	10X	1X	5X	10X	1X	5X	10X	1X	5X	1X	5X			
Kanel																
Sadel																
Podor																
Ranerou																
Pikine														Delta	13.2 mg	100µg & 200µg
Diamnadio														Delta	13.2 mg	
Niayes (Ndioukhane)														Delta & Perm	13.2 mg	100µg & 200µg
Dioffior																
Ndoffane														Delta		
Nioro															13.2 mg	
Koungheul														Perm	13.2 mg	100µg & 200µg
Tambacounda														Perm		
MakaColibantang														Perm		
Salemata				Notfully completed												
Saraya																
Velingara														Delta & Perm	13.2 mg	
Kolda																
Kedougou														Delta & Perm	13.2 mg	100µg & 200µg
Oussouye /Mlomp														Perm		

Tests performed

Tests not performed

NA

ANNEX J-B: INTENSITY OF THE RESISTANCE TO PYRETHROIDS IN *AN. GAMBIAE* S.L. NATURAL POPULATION

Districts	Permethrin				Deltamethrin				Alphacypermethrin			
	1 X	5X	10X	INTENSITY	1 X	5X	1 X	5X	10X	INTENSITY	1 X	5X
Pikine	5.8	73.5	81.3	**High**	39.3	96	91.1	**High**	29.7	77	76	**High**
Diamnadio	2	76.3	98.4	**Moderate**	21.4	93.7	92.3	**High**	8.7	71.7	93	**High**
Ndoffane	12	61.8	-	**High**	44.2	88.6	95.4	**High**	14.7	58.5	-	**High**
Nioro	2.7	-	100	**Moderate**	98.1	-	-	**-**	24.1	-	98.2	**Moderate**
Tambacounda	90.5	100	-	**Low**	93.8	100	-	**Low**	88.4	-	-	**-**
Velingara	39.5	96.1	99	**Moderate**	56.9	95.9	97.1	**High**	64.4	90.6	96.2	**High**

ANNEX K: BLOOD MEAL SOURCES AND ANTHROPOPHILIC RATE OF *AN. GAMBIAE* S.L. AND *AN. FUNESTUS* S.L. BY GEOGRAPHIC AREA (JANUARY 2019-JANUARY 2020)

Geographical zone	*An. gambiae* s.l.										*An. funestus*									
	T	ND	Id*	SIMPLE				MIXT		Ar	T	ND	Id*	SIMPLE				MIXT		Ar
				H	B	S	Ho	H/A	A/A					H	B	S	Ho	H/A	A/A	
Sahelian	25	0	25	4	5	1	7	5	3	0.36	0	0	12	6	0	2	0	4	0	**0.83**
Sahelo-Sudanese	256	7	181	34	52	15	35	25	20	0.33	-	-	-	-	-	-	-	-	-	-
Sudano-Sahelian	823	61	381	28	27	6	235	39	46	0.18	646	34	306	43	39	17	137	24	46	0.22
Sudanese	244	6	119	58	15	3	17	16	10	**0.62**	-	-	-	-	-	-	-	-	-	-
Sudano-Guinean	265	15	125	75	12	1	2	21	14	**0.77**	17	6	11	0	6	2	2	0	1	0.00

NOTE: T= TESTED; ID = NUMBER OF HOSTS SUCCESSFULLY IDENTIFIED; * = IN SOME CASES MULTIPLE HOSTS IDENTIFIED IN ONE MOSQUITO; ND= NOT DETERMINED (BLOOD MEALS WERE NEGATIVE FOR ALL THE ANTIBODIES TESTED). H= HUMAN; B= BOVINE; S= SHEEP (OVINE); HO= HORSE; H/A= HUMAN/ANIMAL; A/A= ANIMAL/ANIMAL; AR= ANTHROPOPHILIC RATE

ANNEX L: TROPHIC PROFILE AND ANTHROPOPHILIC RATES OF *AN. PHAROENSIS* AND *AN. RUFIPES* FEMALES BY GEOGRAPHIC AREA AND BY DISTRICT

Geographical zone	Districts	*An. pharoensis*						*An. rufipes*					
		SIMPLE				MIX		SIMPLE				MIX	
		H	B	S	Ho	HA	AA	H	B	S	Ho	HA	AA
Sahelian	Richard Toll	1	0	0	1	0	0	-	-	-	-	-	-
	Podor	-	-	-	-	-	-	1	2	0	0	0	0
Sahelo-Sudanese	Matam	0	0	1	0	1	0	1	20	11	12	3	6
	Kanel	-	-	-	-	-	-	0	1	1	0	0	2
	Bakel	-	-	-	-	-	-	1	1	1	1	1	0
	Linguere	-	-	-	-	-	-	1	1	0	0	0	0
	Niakhar	-	-	-	-	-	-	0	0	0	1	0	0
	Nioro	1	-	-	-	-	-	0	4	0	2	1	1
	Ndoffane	0	1	2	0	1	1	-	-	-	-	-	-
Sudano-Sahelian	Tambacounda	0	1	0	0	0	0	-	-	-	-	-	-

NOTE: H= HUMAN; A= ANIMAL; H/A= HUMAN/ANIMAL; A/A= ANIMAL/ANIMAL

ANNEX M: TROPHIC PROFILE AND ANTHROPOPHILIC RATES OF *AN. GAMBIAE* S.L. AND *AN. FUNESTUS* S.L. FEMALES BY GEOGRAPHIC AREA AND BY DISTRICT

Geographical zone	Districts	*An. gambiae s.l.*										*An. funestus*									
		T	ND	Id*	SIMPLE				MIX		Ar	T	ND	Id*	SIMPLE				MIX		Ar
					H	B	S	Ho	H/A	A/A					H	B	S	Ho	H/A	A/A	
Sahelian	Richard Toll	6	0	6	1	2	1	1	1	0	0.33		0	10	6	0	1	0	3	0	**0.9**
	Podor	19	0	19	3	3	0	6	4	3	0.37		0	2	0	0	1	0	1	0	**0.5**
Sahelo-Sudanese	Matam	56	0	56	5	31	2	9	1	8	0.11										
	Kanel	10	0	10	1	4	3	0	0	2	0.1										
	Bakel	15	0	15	2	2	5	4	1	1	0.2										
	Ranerou	19	0	19	6	3	1	6	2	1	0.42										
	Linguere	13	0	13	1	3	1	1	7	0	**0.62**										
	Pikine	19	1	9	4	0	1	0	4	0	**0.89**										
	Tivaoune	124	6	59	15	9	2	15	10	8	0.42										
Sudano-Sahelian	Diofior	121	5	58	3	2	0	39	9	5	0.21										
	Niakhar	114	14	50	0	2	0	36	4	8	0.08										
	Koungheul	48	0	24	4	4	0	11	2	3	0.25										
	Kaffrine	2	0	1	0	0	0	1	0	0	0										
	Malem Hoddar	1	1	0	0	0	0	0	0	0	0										
	Nioro	215	11	102	9	4	0	58	10	21	0.19	396	28	184	19	29	9	81	11	35	0.16
	Ndoffane	325	31	147	12	15	6	91	14	9	0.18	250	6	122	24	10	8	56	13	11	0.3
Sudanese	Makacoulibantang	74	2	36	21	3	0	10	2	0	**0.64**										
	Tambacounda	81	1	40	19	9	1	1	5	5	**0.6**										
	Dianke Makha	89	3	43	18	3	2	6	9	5	**0.63**										
Sudano-Guinean	Kedougou	52	0	26	18	2	0	1	4	1	**0.85**	1	0	1	0	1	0	0	0	0	0
	Saraya	17	1	8	1	1	0	0	3	3	**0.5**										
	Salemata	36	0	18	15	0	0	0	3	0	**1**										
	Velingara	88	2	43	25	3	0	0	8	7	**0.77**										
	Kolda	38	8	15	2	6	1	1	2	3	0.27	16	6	10	0	5	2	2	0	1	0
	Oussouye	34	4	15	14	0	0	0	1	0	**1**										

NOTE: T = TESTED; ID = NUMBER OF HOSTS SUCCESSFULLY IDENTIFIED; ND= NOT DETERMINED (BLOOD MEALS WERE NEGATIVE FOR ALL THE ANTIBODIES TESTED). ; H= HUMAN; B= BOVINE; S= SHEEP (OVINE); HO = HORSE**;** H/A = HUMAN/ANIMAL; A/A = ANIMAL/ANIMAL; AR = ANTHROPOPHILIC RATE

* = IN SOME CASES MULTIPLE HOSTS IDENTIFIED IN ONE MOSQUITO.

ANNEX N: SPOROZOITE INDEXES OF *AN. GAMBIAE* S.L. AND *AN. FUNESTUS* S.L. BY GEOGRAPHIC AREA AND DISTRICT

Zone/District	*An. gambiae s.l.*			*An. funestus*		
	T	P	SR	T	P	SR
Sahelian						
Richard Toll	30	3	**0.1**	61	2	0.033
Podor	77	0	0	2	0	0
Sahelo-Sudanese						
Matam	51	3	0.059	-	-	-
Kanel	5	0	0	-	-	-
Bakel	32	1	0.031	-	-	-
Ranerou	32	2	0.063	-	-	-
Linguere	38	1	0.026	-	-	-
Pikine	19	0	0	-	-	-
Tivaoune	14	0	0	-	-	-
Sudano-Sahelian						
Diofior	59	0	0	-	-	-
Niakhar	62	0	0	-	-	-
Koungheul	26	0	0	-	-	-
Nioro	51	0	0	150	1	0.007
Ndoffane	158	0	0	189	2	0.011
Sudanese						
Makacolibantang	85	2	0.024	-	-	-
Tambacounda	94	2	0.021	-	-	-
Dianke Makha	66	1	0.015	-	-	-
Sudano-Guinean						
Kedougou	134	4	0.030	-	-	-
Saraya	91	3	0.033	2	0	0
Salemata	57	3	0.053	-	-	-
Velingara	132	1	0.008	-	-	-
Kolda	64	4	0.063	-	-	-
Oussouye	69	0	0	-	-	-

Note: T = total tested; P = positive; SR = sporozoite rates

ANNEX O: MONTHLY INFECTION RATE OF VECTOR SPECIES (JANUARY 2019-JANUARY 2020)

	January-19		February		March		May		July		August		September		October		November		Decembrer19		January-20	
Zone	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**	**T**	**P**
***An. funestus* s.l.**																						
Sudano-Sahelian	59	0			71	**1**	53	**1**	56	0			71	0			29	**1**				
Sudano-Guinean													2	0								
***An. gambiae* s.l.**																						
Sahelo-Sudanese															14	0						
Sudano-Sahelian	38	0			34	0	29	0	57	0			168	0			29	0	1	0		
Sudanese									70	**3**			170	**2**					5	0		
Sudano-Guinean			2	0					10	0	117	0	257	**6**	118	**5**			36	**4**	7	0

Note: T: tested; P: positive

ANNEX P: INFECTION RATE OF *AN. PHAROENSIS AND AN. NILI* BY GEOGRAPHIC AREA

Zone/District	*An. pharoensis*			*An. nili*		
	Tested	Positive	SI	T	P	SI
Sahelian						
Richard Toll	12	0	0	-	-	-
Podor	22	0	0	-	-	-
Sahelo-Sudanese						
Matam	37	0	0	-	-	-
Kanel	1	0	0	-	-	-
Bakel	-	-	-	-	-	-
Ranerou	2	0	0	-	-	-
Linguere	-	-	-	-	-	-
Pikine	-	-	-	-	-	-
Tivaoune	-	-	-	-	-	-
Sudano-Sahelian						
Diofior	-	-	-	-	-	-
Niakhar	-	-	-	-	-	-
Koungheul	8	0	-	-	-	-
Nioro	13	0	-	-	-	-
Ndoffane	1	0	-	-	-	-
Sudanese						
Makacolibantang	-	-	-	-	-	-
Tambacounda	-	-	-	-	-	-
Dianke Makha	-	-	-	1	0	-
Sudano-Guinean						
Kedougou	-	-	-	4	0	-
Saraya	1	0	-	3	0	-
Salemata	-	-	-	2	0	-
Velingara	3	0	-	1	0	-
Kolda	-	-	-	-	-	-
Oussouye	-	-	-	-	-	-

ANNEX Q: ENTOMOLOGICAL INOCULATION RATE PER NIGHT OF *AN. GAMBIAE* S.L. FEMALES IN THE SURVEYED SITES (JANUARY 2019-JANUARY 2020)

Geographic zone	District	Indoor			Outdoor			Total		
		HBR	CSI	EIR	HBR	CSI	EIR	HBR	CSI	EIR
Sahelian	Richard Toll	0.5			0.333			0.417	0.1	**0.042**
	Podor	0.994			1.15			1.072		
Sahelo-Sudanese	Matam	0.783			0.633			0.708	0.059	**0.042**
	Kanel	0.111			0.028			0.070		
	Bakel	0.544			0.328			0.436	0.031	**0.014**
	Ranerou	0.589			0.3			0.445	0.063	**0.028**
	Linguere	0.617			0.456			0.537	0.026	**0.014**
	Pikine	0.5			0.29			0.396		
	Tivaoune	0.188			0.17			0.177		
Sudano-Sahelian	Diofior	17.667			12.13			14.896		
	Niakhar	3.875			2.63			3.25		
	Koungheul	0.222			0.14			0.181		
	Nioro	0.375			0.6			0.486		
	Ndoffane	1.375			2.53			1.951		
Sudanese	Makacolibantang	1.917	**0.03**	**0.05**	2	0.02	**0.04**	1.958	0.0235	**0.05**
	Tambacounda	26.938			20.06	0.04	**0.89**	23.5	0.0213	**0.5**
	Dianke Makha	20.611	**0.03**	**0.69**	22.17			21.389	0.0152	**0.32**
Sudano-Guinean	Kedougou	26.347	**0.03**	**0.77**	16.56	**0.03**	**0.5**	21.451	0.03	**0.64**
	Saraya	14.542	**0.05**	**0.7**	22.58			18.563	0.033	**0.61**
	Salemata	9.333	**0.07**	**0.64**	9.42	0.04	**0.34**	9.375	0.0526	**0.49**
	Velingara	7.5	**0.01**	**0.11**	9			8.25	0.0076	**0.06**
	Kolda	1.972	**0.07**	**0.14**	1.17	0.04	**0.05**	1.569	0.0625	**0.1**
	Oussouye	11.972			16.47			14.222		

Note: HBR = human biting rate, CSI = circumsporozoite index, EIR = entomological inoculation rate (b/p/n)

ANNEX R: ENTOMOLOGICAL INOCULATION RATE PER NIGHT OF *AN. FUNESTUS* S.L. FEMALES IN THE DIFFERENT SITES MONITORED (JANUARY 2019-JANUARY 2020)

District	Indoor				Outdoor				Total		
	HBR	SR	EIR		HBR	SR	EIR		HBR	SR	EIR
Richard Toll	0.561				0.95				0.756	**0.033**	**0.025**
Podor	0.028	0	0		0.056	0	0		0.042	0	0
Nioro	2.014	**0.01**	**0.02**		1.67	0	0		1.84	**0.0067**	**0.01**
Ndoffane	3.944	0	0		6.81	0.02	0.13		5.375	**0.0106**	**0.06**
Saraya	0.042	0	0		0.17	0	0		0.104	0	0

HBR = Human Biting Rate SR = Sporozoite rates EIR = Entomological Inoculation Rate (b/p/n)

ANNEX S: MONTHLY ENTOMOLOGICAL INOCULATION RATE OF VECTOR SPECIES (JANUARY 2019-JANUARY 2020)

Zone	January-19	February	March	May	July	August	September	October	November
***An. funestus* s.l.**									
Sudano-Sahelian	0	0	**0.058**	**0.015**	0	0	0	0	**0.069**
Sudano-Guinean	0	0	0	0	0	0	0	0	0
***An. gambiae* s.l.**									
Sahelo-Sudanese	0	0	0	0	0	0	0	0	0
Sudano-Sahelian	0	0	0	0	0	0	0	0	0
Sudanese	0	0	0	0	**0.042**	0	**0.631**	0	0
Sudano-Guinean	0	0	0	0	0	0	**0.913**	**0.259**	0

ANNEX T: DISTRIBUTION OF THE AN. GAMBIAE COMPLEX MEMBERS

Geographic zone	Total	*Hybrid An. coluzzii/An. gambiae*	*An. arabiensis*	*An. coluzzii*	*An. gambiae*	*An. melas*
Sahelian	75	-	73 (97.33)	-	2 (2.67)	-
Sahelo-Sudanese	242	-	238 (98.35)	-	4 (1.65)	-
Sudano-sahelien	803	-	771 (96.01)	13 (1.62)	13 (1.62)	6 (0.75)
Sudanese	359	2 (0.56)	149 (41.50)	12 (3.34)	196 (54.60)	-
Sudano-Guinean	675	8 (1.19)	181 (26.81)	39 (5.78)	447 (66.22)	-

ANNEX U: *AN. GAMBIAE* S.L. SPECIES COMPOSITION IN THE SURVEYED DISTRICTS

Geographic zone		Total	*An. coluzzii / An. gambiae* (%)	*An. arabiensis* (%)	*An. coluzzii* (%)	*An. gambiae* (%)	*An. melas* (%)
Sahelian	Richard Toll	24	-	24 (100)	-	0	-
	Podor	51	-	49 (96.08)	-	2 (3.92)	-
Sahelo-Sudanese	Matam	36	-	33 (91.67)	-	3 (8.33)	-
	Kanel	5	-	5 (100)	-	0	-
	Bakel	28	-	28 (100)	-	0	-
	Ranerou	31	-	30 (96.77)	-	1 (3.23)	-
	Linguere	26	-	26 (100)	-	0	-
	Pikine	32	-	32 (100)	-	-	-
	Tivaoune	84	-	84 (100)	-	-	-
Sudano-sahelien	Diofior	120	-	115 (95.83)	2 (1.67)	3 (2.5)	-
	Koungheul	53	-	46 (86.79)	6 (11.32)	1 (1.89)	-
	Niakhar	125	-	124 (99.2)	-	1 (0.8)	-

	Ndoffane	329	-	319 (96.96)	3 (0.91)	1 (0.3)	6 (1.83)
	Nioro	176	-	167 (94.89)	2 (1.14)	7 (3.97)	-
Sudanese	Tambacounda	132	-	59 (44.7)	6 (4.55)	67 (50.75)	-
	Makakoulibantang	123	2 (1.63)	59 (47.97)	5 (4.07)	57 (46.33)	-
	Diankhe Makha	104	-	31 (29.81)	1 (0.96)	72 (69.23)	-
Sudano-Guinean	Kedougou	166	-	36 (21.69)	2 (1.2)	128 (77.11)	-
	Kolda	85	1 (1.18)	29 (34.12)	8 (9.41)	47 (55.29)	-
	Saraya	77	2 (2.6)	23 (29.87)	11 (14.29)	41 (53.24)	-
	Oussouye	88	-	13 (14.77)	7 (7.95)	68 (77.28)	-
	Salemata	85	5 (5.88)	12 (14.12)	1 (1.18)	67 (78.82)	-
	Velingara	174	-	68 (39.08)	10 (5.75)	96 (55.17)	-