PMI | Africa IRS (AIRS) Project

Indoor Residual Spraying (IRS 2) Task Order Six

SENEGAL 2016 ENTOMOLOGICAL MONITORING REPORT

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SENEGAL 2016 ENTOMOLOGICAL MONITORING REPORT

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ACRONYMS

AIRS	Africa Indoor Residual Spraying Project
CDC	Centers for Disease Control and Prevention
DDT	dichlorodiphenyltrichloroethane
FST	Faculty of Sciences and Technology
HBR	Human Biting Rate
HLC	Human Landing Catch
IRD	Indoor Resting Densities
IRS	Indoor Residual Spraying
KDR	Knock Down Resistant
LEVP	Laboratory of Vector and Parasite Ecology
NMCP	National Malaria Control Program
PCR	Polymerase Chain Reaction
PMI	President's Malaria Initiative
PR	Parity Rate
PSC	Pyrethrum Spray Catch
UCAD	University of Cheikh Anta Diop
USAID	United States Agency for International Development
WHO	World Health Organization

EXECUTIVE SUMMARY

The residual efficacy of indoor residual spraying (IRS) with pirimiphos-methyl (Actellic CS 300) using a susceptible strain of *Anopheles gambiae* s.s. was generally between two to five months for mud and concrete walls (according to World Health Organization (WHO) criteria of >80% mortality). Residual performance was shortest in Malem Hodar where mortality was only >80% for 1 month after spraying, although mortality remained >70% after 3 months on mud and cement walls. Elsewhere, mortality was >80% on cement walls for 4-5 months. Strictly following WHO criteria, residual performance was 2-4 months on mud walls, however in most sites mortality remained >70% for 5 months.

WHO cylinder tests indicated full susceptibility of wild *An. gambiae* s.l. to pirimiphos-methyl (0.25%) in all 15 sites tested, including all four IRS districts. Resistance to bendiocarb (0.1%) was only recorded in the Dakar suburbs of Pikine and UCAD campus, with full susceptibility recorded in IRS districts. Resistance to the pyrethroid insecticides permethrin, deltamethrin and lambda-cyhalothrin was widespread throughout Senegal, with the lowest mortality rates recorded in the Dakar suburbs.

Morphological identification of *Anopheles* from human landing catch (HLC) and pyrethrum spray catch (PSC) indicated that >89 percent were *An. gambiae* s.l. in Koungheul, Malem Hodar and Koumpentoum districts, 45 percent were *An. funestus* s.l. and 45 percent were *An. gambiae* s.l. in Nioro. HLC and PSC collections were conducted in each IRS district in two sprayed hot spot villages, two unsprayed low transmission villages (internal controls), and two unsprayed hot spot villages in a neighboring district (external controls). The human biting rate was expected to be greater in the unsprayed external controls than in sprayed hot spots or unsprayed non-hot spot villages. This pattern was observed in Koumpentoum where the mean biting rate was 4.5 bites per person per night in the unsprayed external controls, compared to 0.3 bites per person per night in the sprayed hot spots and 0.1 in the unsprayed non-hot spot villages. In Koungheul and Malem Hodar the mean biting rate was low (<2 bites per person per night) every month regardless of whether the villages were hot spots, low transmission, unsprayed or sprayed. In Nioro district there was a seasonal biting peak of *An. gambiae* s.l. and *An. funestus* s.l. in October (two months after spraying) to the same magnitude regardless of whether villages were sprayed, unsprayed, hot spot or low transmission.

The indoor resting density (IRD) of *An. gambiae* s.l. was greater in external sentinel sites (unsprayed hot spots) than in sprayed villages, except in Nioro district where it was higher in the low transmission villages. IRDs were less than two *An. gambiae* s.l. per room in all sprayed villages except for Nioro where the mean was four per room per day. Lower parity rates were recorded in sprayed villages of Koungheul and Malem Hodar districts than for unsprayed control villages. This may indicate that IRS reduced the mean life expectancy of *An. gambiae* s.l. in these two districts. There was no difference in parity rates between sprayed and unsprayed sites in Koumpentoum and Nioro districts.

Nationwide vector monitoring of selected sentinel sites indicated particularly high *An. gambiae* s.l. biting rates in Kedougou (Southern Senegal) at 47 bites per person per night (July and September), while PSC only caught a mean of two *An. gambiae* s.l. per room per day. A similar trend was observed in the former IRS site of Velingara with a mean of 11 *An. gambiae* s.l. bites per person per night, but only two captured per room per day by PSC. In 2017, there will be an operational research component to better understand vector behavior in Southern Senegal with a view to improved future vector control. In September, *An. gambiae* s.l. biting rates in the former IRS site of Richard Toll in Northern Senegal were low at <1 bite per person per night.

The entomology data presented does not convincingly demonstrate that IRS is having a substantial impact on the local malaria vector population in the four IRS districts. Therefore, the team recommends that 2016 malaria case data from IRS health districts and unsprayed control villages should be analyzed together with entomology data to determine whether the current strategy of hot spot spraying is effective in Senegal.

1. INTRODUCTION

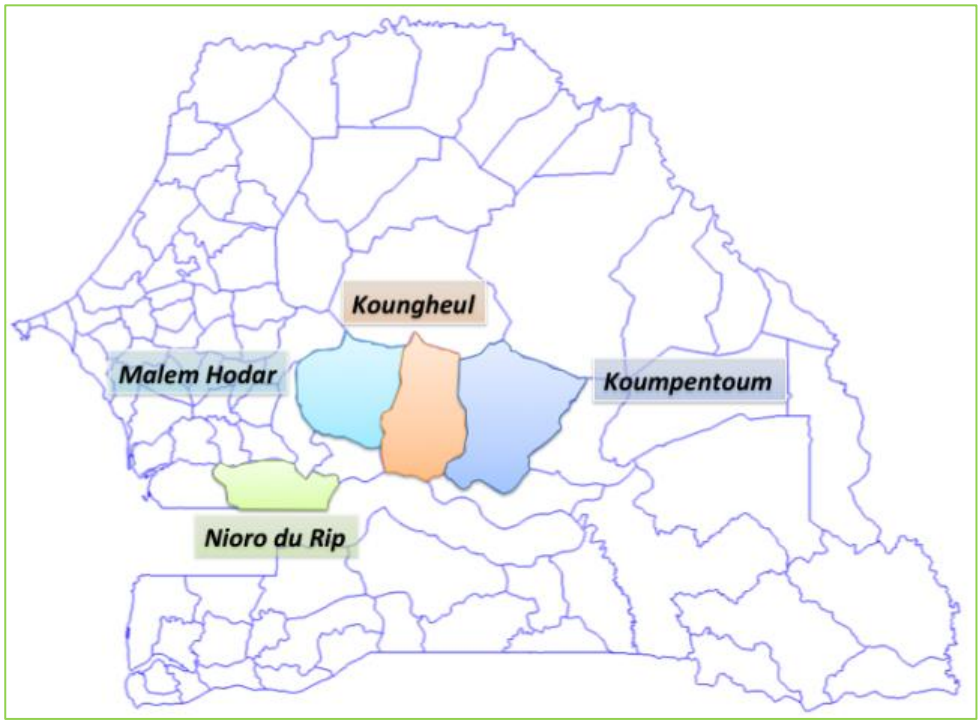
In Senegal, IRS implementation began as a pilot in three health districts (Velingara, Nioro and Richard-Toll) in 2007. Based on the results achieved, the National Malaria Control Program (NMCP) and PMI decided to expand IRS to new districts in 2010 (Guinguinéo, Malem Hoddar, and Koumpentoum). Since 2013, AIRS/Senegal has been implementing IRS in four districts.

In 2015, AIRS started implementing IRS in Koumpentoum, Koungheul, Malem Hoddar and Nioro (Fig. 1) with a new strategy, which targets health posts with high malaria incidence (> 15 cases/1000 inhabitants), hot spots inside the health district. This new approach involved decreasing the number of sentinel sites per district (from five to four in IRS districts) and increasing the entomology monitoring frequency to be performed monthly.

The Laboratory of Vector and Parasite Ecology (LEVP) of the Faculty of Science and Technology (FST) at the UCAD in Dakar, in collaboration with NMCP, has been implementing entomological monitoring activities in Senegal since 2007. For the last several years, LEVP has received a direct contract from PMI/Senegal for the implementation of entomological monitoring activities. Since 2015, while LEVP continued the implementation of entomological monitoring activities, it was subcontracted through the PMI AIRS Project.

We present the main results of the rainy season ('winter' period July-November) for the 2016 campaign in this report.

Figure 1. Geographical locations of the PMI-Senegal IRS districts sprayed for the 2016 campaign



2. METHODOLOGY

2.1 DISTRICTS AND SENTINEL VILLAGES FOR THE 2016 CAMPAIGN

In each IRS district, the AIRS Senegal team selected four sentinel villages: two from malaria hot spot villages (health posts that received IRS in 2016) and two from low transmission non-hot spots (health posts that did not receive IRS in 2016). The team selected an additional two 'external' malaria hot spot sites from a neighboring control district that did not receive IRS in 2016. Therefore, the total number of sentinel sites was two sprayed hot spots, two internal controls and two external controls for each of the four spray districts (total of 24 sites) (Table1).

TABLE 1: SENTINEL VILLAGES SELECTED IN IRS DISTRICTS AND THEIR CONTROL, JULY 2016-MARCH 2017

Year of monitoring	Health district	Sprayed sentinel villages	Internal control (unsprayed)	External control (unsprayed)
6th	Koumpentoum	Koumaré and Village1	Kouthiaba and Syll Sérigne Malick	Koussanar and Lycounda (Tambacounda)
6th	Malem Hodar	Makka Bella, Tip Saloum and Touba Guéyène¥	Diankhé Souf and Ndioum Ngainth	Pété and Thiamène Cathiote (Kaffrine)
5th	Koungheul	Pakala and Ida Mouride	Touba Aly Mbenda and Nguérane Goumack	Malem Thiérigne (Malem Hodar), Wey Naan and Toune Mandakh¥ (Kaffrine),
2nd	Nioro	Bamba Diakhatou andNdramé Ndimb	Paoskoto and Camara	Tawa Mboudayea and Darou Mbitéyène (Ndoffane)

¥ : Touba Guéyène and Toune Mandakh were replaced respectively by Tip Saloum and Malem Thiérigne after one month of monitoring due to inaccessibility

Key Terminology
Sprayed = hot spot village sprayed with Actellic CS in 2016.
Internal control = low transmission unsprayed village within the same district as the sprayed site.
External control = hot spot village located in neighboring unsprayed district.

In other sites (Table 2), which are of entomological interest, the team monitored one (Richard Toll, Senegal River Valley) or two times (Kedougou, Velingara, Niayes) during the rainy season. For the other districts (Niakhar, Diourbel, Pikine and Guiguineo), only one visit was done to collect larvae for susceptibility tests. The geographical locations of sentinel sites are represented in Fig 2.

Figure 2. Geographical locations of districts with entomological monitoring

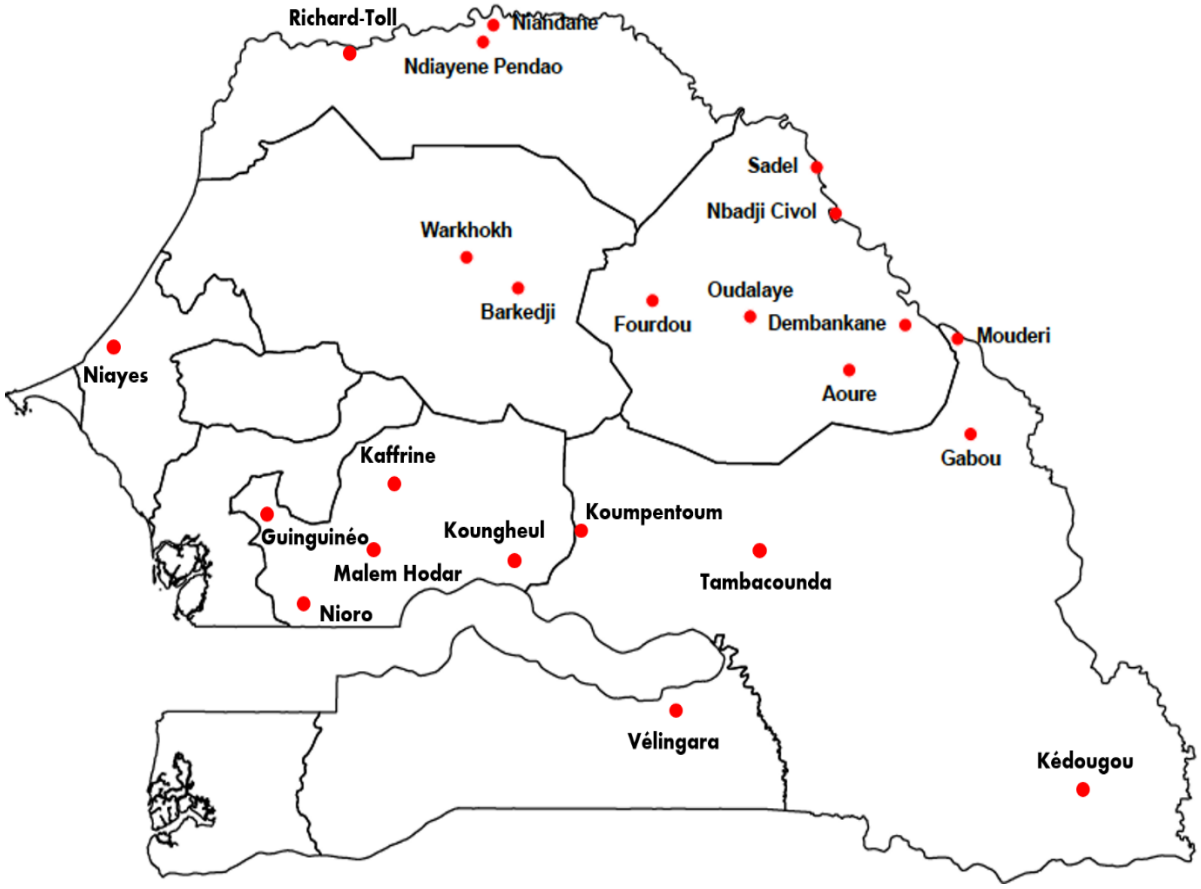


TABLE 2: SENTINEL VILLAGES SELECTED IN UNSPRAYED DISTRICTS

Health district	Sentinel villages	Entomological activities	Frequency
Northern and East Central Districts			
Niayes	Ngadiaga, Ndiambalo, Thiaye, Touba Taw Fekh and Beer	HLC indoors/outdoors, indoor PSC, parity rates, susceptibility tests.	Once every two months
Richard-Toll	Mbagame, Rosso Béthio, Ndiandiou, Maka Diama, Taba Darou Salam, Mallé, Gnith, Ronkh, Khor and	HLC indoors/outdoors, indoor PSC, parity rates, susceptibility tests	Once during the rainy season
Linguere*	Barkedji & Ouarkhokh	HLC indoors/outdoors, indoor PSC, parity rates	
Podor*	Ndiayène Pendao & Niandane	HLC indoors/outdoors, indoor PSC, parity rates	
Ranerou*	Oudalaye & Fourdou	HLC indoors/outdoors, indoor PSC, parity rates	
Matam*	Sadel & Nabadji Ciwol	HLC indoors/outdoors, indoor PSC, parity rates	
Kanel*	Haouré & Dembankané	HLC indoors/outdoors, indoor PSC, parity rates	
Bakel*	Gabou & Moudéry	HLC indoors/outdoors, indoor PSC, parity rates	
Niakhar	Niakhar	Susceptibility testing	Once
Diourbel	Keur Mbaye Sarr	Susceptibility testing	Once
Pikine et Guédiawaye	(Flooded areas in suburbs of Dakar)	Susceptibility testing	Once
Southern Districts			
Tambacounda	Koussanar¥, Lycounda¥, Badi	HLC indoors/outdoors, indoor PSC, parity rates	Once per month
Ndoffane	Tawa Mboudaye¥ and Darou Mbitéyène¥	HLC indoors/outdoors, indoor PSC, parity rates, susceptibility	
Kaffrine	Pété¥, Thiamène Cathiote¥ and Wey Naan¥	HLC indoors/outdoors, indoor PSC, parity	
Malem Hodar	Malem Thiérigne¥	HLC indoors/outdoors, indoor PSC, parity	
Kédougou	Tomboronkoto & Bandafassi	HLC indoors/outdoors, indoor PSC, parity rates, susceptibility	Once every two months
Vélingara	Madina Dianguet &	HLC indoors/outdoors, indoor	
Guinguineo	Guinguineo city	Susceptibility testing	Once

Health district	Sentinel villages	Entomological activities	Frequency

¥ External control villages of IRS districts
* Districts of Senegal River Valley

2.2 INSECTICIDES SPRAYED

This campaign was based for a second year on 2015 hot spots, with IRS targeted in the villages of the health posts where residual malaria transmission has been reported with malaria incidence greater than 15 confirmed cases per 1000 inhabitants. The teams sprayed pirimiphos-methyl (Actellic CS 300) at 1g/m² in the districts of Koungheul, Koumpentoum, Malem Hodar, and Nioro. Table 3 illustrates spraying and testing dates.

TABLE 3: IRS TREATMENT DATES AND TIMING OF CONE BIOASSAY IN THE IRS SENTINEL VILLAGES IN 2016

District	Sentinel Site	Date of spray	1st bioassay	2nd bioassay	3rd bioassay	4th bioassay	5th bioassay
Koungheul	Pakala	28/07/2016	11/08	30/08	04/10	05/11	
	Ida Mouride	02/08/2016	10/08	31/08	12/10	04/11	
Malem Hodar	Makka Bella	23/07/2016	10/08	30/08	04/10	05/11	
	Tip Saloum	24/07/2016	-	06/09	05/10	06/11	
	Touba Guéyène*	26/07/2016	15/08	-	-	-	-
Koumpentoum	Koumaré	26/07/2016	10/08	02/09	05/10	10/11	
	Village 1	18/07/2016	13/08	31/08	04/10	11/11	
Nioro	Bamba Diakhatou	11/07/2016	11/08	30/08	03/10	05/11	
	Ndramé Ndimb	30/07/2016	15/08	01/09	04/10	06/11	

* This village has been replaced by Tip Saloum after one month of monitoring because of its inaccessibility during rainy season.

2.3 EFFECTIVENESS OF INDOOR RESIDUAL SPRAYING

Treatment effectiveness in each IRS district was determined in 10 sprayed residential rooms chosen in two treated villages (five per village), with two untreated control rooms (one per village). The choice of rooms in the villages was done by lottery and selected rooms were repeatedly tested each month during monitoring.

Cone bioassays were performed in each room according to WHO standard protocols. Female mosquitoes of a susceptible strain of *Anopheles gambiae* s.s. maintained at the insectary (Research Institute for Development, Institut Pasteur of Dakar, and Parasite Vector Control Service) were used for this purpose. Three cones were placed on each wall and 10 mosquitoes were exposed in each cone. The location of the cones on the walls changed slightly each month as it was noted that tape used for attaching cones removed part of the wall surface when removed. For the negative controls, three cones were fixed to a piece of untreated white paper and then attached to an untreated wall. Mortality of test mosquitoes was recorded 24 hours after exposure, with Abbott's correction implemented if mortality was between 5 percent and 20 percent in the negative controls. The IRS treatment was considered effective if the mortality was greater than 80 percent, as described by WHO.

2.4 MONITORING VECTOR DYNAMICS

Sampling of vector populations was made by i) indoor collections in homes by PSC and ii) night time HLC indoors and outdoors.

The project carried out collections of indoor resting mosquitoes by PSC in sprayed and control districts, in 10 rooms per village. This collection method was compared in a sub-sample of districts with the Prokopack aspirator to compare performance of both methods. Prokopack aspirators were tested to determine whether efficacy of PSC was partially diminished due to pyrethroid resistance. Prokopack collections were carried out in the same rooms where PSC was applied on two consecutive days according to the formula: PSC followed by Prokopack in the first five rooms and Prokopack before PSC in the last five rooms in each village chosen for this study.

The project carried out HLCs in sprayed villages as well as internal and external control villages. In each village, HLC was conducted for two consecutive nights in three houses by six humans per night located indoors and outdoors (two humans per house). This method of collection was also compared with CDC light traps in a subsample of districts to compare performance. CDC light traps were tested with the aim of increasing the number of houses sampled in 2017 if equivalent to HLC (as CDC light traps require fewer human resources than HLC). In the villages selected for this comparison, four houses were used for trapping each night both indoors and outdoors following a Latin square rotation.

In the field, the project team morphologically identified (genus / species) collected specimens and counted. A sub-sample of host-seeking females were dissected for the determination of parity rate. Blood-fed females were individually preserved in micro-tubes for determination of blood meal source. All captured females were individually conserved in micro-tubes for laboratory analysis (species identification, infection and knock down resistant (kdr) gene detection, etc).

2.5 WHO SUSCEPTIBILITY TESTS

The project carried out insecticide susceptibility tests in four sprayed districts and in selected unsprayed districts. Adult females of 2-5 days old that were collected from the wild as larvae were used for testing.

Insecticides tested

The tests were carried out in WHO-test cylinders with papers impregnated with diagnostic concentrations of the following insecticides:

Pyrethroids:

- Deltamethrin 0.05 percent
- Lambda-cyhalothrin 0.05 percent
- Permethrin 0.75 percent

Organophosphates:

- Pirimiphos-methyl 0.25 percent

Carbamates:

- Bendiocarb 0.1 percent

The project team exposed mosquitoes to treated papers for one hour and recorded mortality after 24 hours post-exposure.

For each insecticide, at least 100 mosquitoes were tested in four replicates of 25. An accompanying negative control was always tested. The basis of the interpretation of the results is presented in the table below based on WHO 2013 guidelines.

Susceptibility status	WHO threshold	Additional threshold	Observations
Susceptible	98-100%	98-100%	Susceptibility confirmed
Resistant	Less than 98%	90-98%	Resistance suspected
		Less than 90%	Resistance confirmed

2.6 CDC BOTTLE BIOASSAYS FOR RESISTANCE MONITORING

The project carried out insecticide susceptibility tests from October through November in the four IRS districts (Koungheul, Koumpentoum, Malem Hodar, and Nioro) and in six untreated districts: Kédougou, Guinguinéo, Richard Toll, Rufisque, and Dakar suburbs (Pikine and Guediawaye). Female *An. gambiae* s.l. from wild larvae that were 2- to 5-days-old were used for these tests.

The specimens were exposed to the diagnostic time of 30 minutes and the tests were corrected with Abbott's formula control with mortality between 3 and 10%. The interpretation of the results is based on WHO criteria for susceptibly tests.

2.7 LABORATORY MOLECULAR ANALYSES

From *An. gambie s.l.* collected by HLC, infective female detection was made by the method of Enzyme-Linked Immuno-Sorbent Assay circumsporozoite (CSP ELISA) described by Burkot et al., (1984) and slightly modified by Wirtz et al., (1987).

From *An. gambie s.l.* collected by PSC, the origin of blood meals was determined by the direct ELISA method described by Beier et al. (1986).

The molecular identification of *An. gambiae* sibling species was performed on a subsample of living and dead female from susceptibility tests, HLC and PSC. The molecular identification was performed by polymerase chain reaction (PCR) according to the protocol of Wilkins et al. (2006).

Laboratory data will be submitted in a supplementary report in February 2017.

3. RESULTS

3.1 RESIDUAL EFFECTIVENESS OF PIRIMIPHOS-METHYL IRS AGAINST A SUSCEPTIBLE STRAIN OF *ANOPHELES GAMBIAE* S.S. IN CONE BIOASSAY

Cone bioassay of walls (mud and concrete) sprayed with pirimiphos-methyl (Actellic CS 300) produced mean mortality rates greater than the WHO threshold of 80 percent in three of four districts three to five months after spraying. Testing will continue until mortality is <80 percent for two consecutive months in all districts and the team will report results to PMI as a supplementary document.

3.1.1 KOUNGHEUL DISTRICT

In total, 911 *An. gambiae* s.s. were exposed on mud walls and 915 on concrete walls to monitor the effectiveness of pirimiphos-methyl (Actellic CS 300) in Koungheul district. Mortality was 100 percent for all rooms tested one month after treatment. Mortality was greater than 80 percent on concrete walls for five months and for three months on mud walls, although mortality was still 79% after 5 month (Table 4).

3.1.2 KOUMPENTOUM DISTRICT

In total, 1,656 *An. gambiae* s.s. were exposed. The sprayed walls were effective after five months with a mortality of 79 percent on mud walls and 93 percent on concrete walls (Table 5).

3.1.3 MALEM HODAR DISTRICT

In total, 894 *An. gambiae* s.s. were exposed to mud walls compared with 956 for concrete. Mortality was only greater than 80 percent for one month on mud and cement, with mortality of 73 percent on mud walls and 78 percent on concrete walls after three months (Table 6).

3.1.4 NIORO DISTRICT

A total of 1,825 *An. gambiae* s.s. were exposed to the walls (1211 on mud walls compared to 614 on concrete). The insecticide remained effective four months after spraying with 91 percent on mud walls and 82 percent on concrete walls (Table 7).

TABLE 4: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) ON MUD AND CONCRETE WALLS AGAINST A SUSCEPTIBLE INSECTARY STRAIN OF *AN. GAMBIAE* S.S. IN THE DISTRICT OF KOUNGHEUL (AUGUST TO NOVEMBER)

Time after spraying (months)		Mud						Cement						Total					
		< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months
Exposed	IRS	152	150	152	153	146	158	153	150	155	149	151	157	305	300	307	302	297	315
	Control	30	30	30	30	30	31	30	30	31	30	30	32	60	60	61	61	60	63
Mortality 24h	IRS	152	150	137	138	114	127	152	150	154	122	104	130	304	300	291	260	218	257
	Control	0	0	0	3	3	2	1	0	2	3	2	0	1	0	2	6	5	2
Mortality rate (%)	IRS	**100**	**100**	**90.1**	**89.1***	**75.6***	**79***	**99.3**	**100**	**99.3***	**79.9***	**66.6***	**82.8**	**99.7**	**100**	**94.8**	**84.6***	**71***	**81.6**
	Control	0	0	0	10	10	6.5	3.3	0	6.5	10	6.7	0	1.7	0	3.3	9.8	8.3	3.2

* = Corrected mortality

<1 month = August; 1 month = September; 2 months = October; 3 months = November, 4 months= December, 5 months= January 2017

TABLE 5: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) ON MUD AND CONCRETE WALLS AGAINST A SUSCEPTIBLE INSECTARY STRAIN OF *AN. GAMBIAE* S.S. IN THE DISTRICT OF KOUMPENTOUM

Time after spraying (months)		Mud						Cement						Total					
		< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months
Exposed	IRS	90	210	210	210	216	210	60	90	90	90	90	90	150	300	300	300	306	300
	Control	30	60	60	60	61	60	-	-	-	-	-	-	30	60	60	60	61	60
Mortality 24h	IRS	90	210	191	134	154	166	60	90	88	48	89	84	150	300	279	182	243	250
	Control	0	0	4	2	3	2	-	-	-	-	-	-	0	0	4	2	3	2
Mortality rate (%)	IRS	**100**	**100**	**90.3***	**63.8**	**71.3**	**79**	**100**	**100**	**97.6***	**53.3**	**98.9**	**93.3**	**100**	**100**	**92.5***	**60.7**	**79.4**	**83.3**
	Control	0	0	6.7	3.3	4.9	3.3	-	-	-	-	-	-	0	0	6.7	3.3	4.9	3.3

TABLE 6: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) ON MUD AND CONCRETE WALLS AGAINST A SUSCEPTIBLE INSECTARY STRAIN OF *AN. GAMBIAE* S.S. IN THE DISTRICT OF MALEM HODAR

Time after spraying (months)		Mud						Cement						Total					
		< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months
Exposed	IRS	125	155	149	151	155	159	186	167	148	152	152	151	311	322	297	303	307	310
	Control	32	33	30	30	30	30	32	31	31	32	30	30	64	64	61	60	60	60
Mortality 24h	IRS	125	154	107	110	66	83	185	166	111	119	57	74	310	320	218	229	123	157
	Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mortality rate (%)	IRS	**100**	**99.4**	**71.8**	**72.8**	**42.6**	**52.2**	**99.5**	**99.4**	**75**	**78.3**	**37.5**	**49**	**99.7**	**99.4**	**73.4**	**75.6**	**40**	**50.6**
	Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 7: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) ON MUD AND CONCRETE WALLS AGAINST A SUSCEPTIBLE OF *AN. GAMBIAE* S.S. IN THE DISTRICT OF NIORO

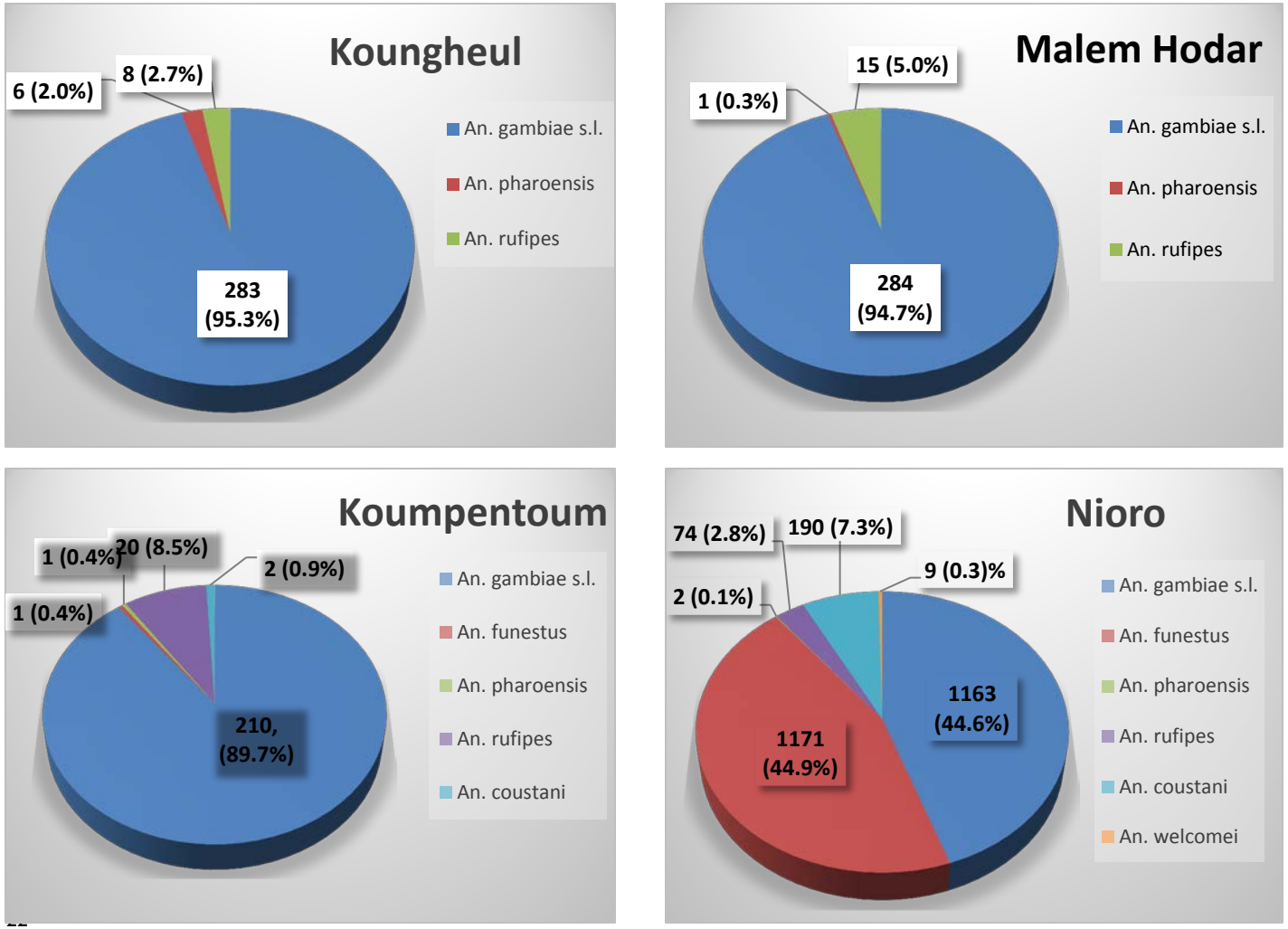
Time after spraying (months)		Mud						Cement						Total					
		< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months	< 1 month	1 month	2 months	3 months	4 months	5 months
Exposed	IRS	68	238	234	240	235	196	100	93	98	95	105	123	168	331	332	335	340	319
	Control	36	71	67	69	73	67	-	-	-	-	-	-	36	71	67	69	73	67
Mortality 24h	IRS	68	225	220	192	215	135	100	93	98	94	87	42	168	318	318	286	302	177
	Control	5	4	1	3	4	0	-	-	-	-	-	-	5	4	1	3	4	0
Mortality rate (%)	IRS	**100***	**94.2***	**94**	**80**	**91***	**68.9**	**100***	**100***	**100**	**98.9**	**81.8***	**34.1**	**100***	**95.8***	**95.8**	**85.4**	**88.2***	**55.5**
	Control	13.9	5.6	1.5	4.3	5.5	0	-	-	-	-	-	-	13.9	5.6	1.5	4.3	5.5	0

3.2 VECTOR POPULATION DYNAMICS IN IRS DISTRICTS

3.2.1 COMPOSITION OF SPECIES

Anopheles gambiae s.l. was the main species group caught in resting collections (PSC and Prokopack) and biting collections (HLC and CDC light trap) in the districts of Koumpentoum, Koungheul and Malem Hodar. In Nioro district, *An. funestus* s.l. and *An. gambiae* s.l. were captured in the same proportion (Fig. 3). Other *Anopheles* collected included *An. pharoensis* and *An. rufipes* in all IRS distrcits and *An. coustani* in Nioro.

Figure 3: Species composition of *Anopheles* caught by HLC and PSC during the rainy season in IRS districts



3.2.2 HUMAN BITING RATE (HBR)

3.2.2.1 HUMAN BITING RATE AT DISTRICT LEVEL (SPRAYED AND UNSPRAYED VILLAGES COMBINED)

Vector populations of *An. gambiae* s.l. increased during the rainy season with the highest biting rate in Nioro District and peak biting rates recorded in October for all districts except in Malem Hodar where the peak biting rate was recorded in November (Fig 4). In Nioro *An. funestus* s.l. was also present with a higher biting rate than *An. gambiae* s.l. and a peak in November (Fig 5).

Figure 4: Human biting rate of *Anopheles gambiae* s.l. in IRS districts (sprayed and unsprayed villages combined) during the rainy season.

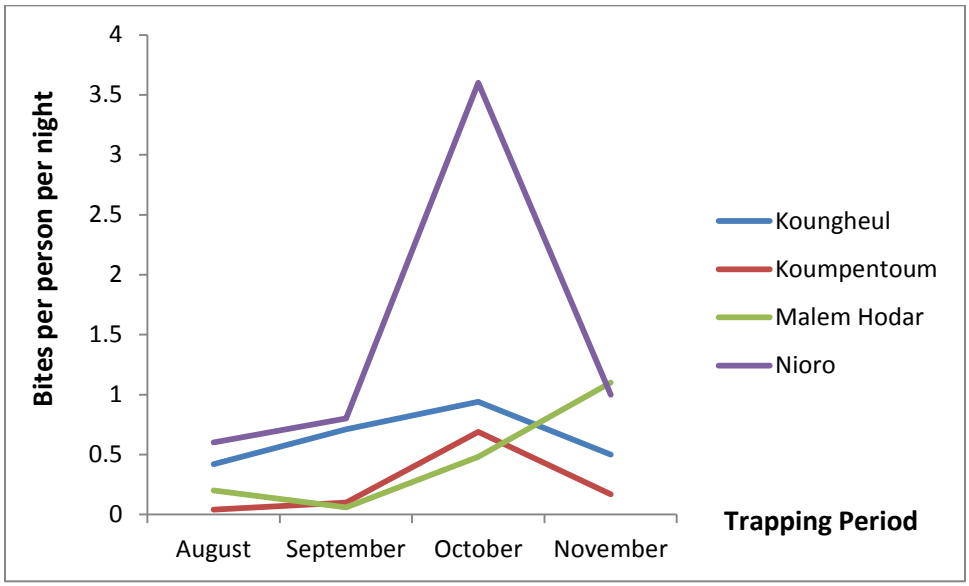
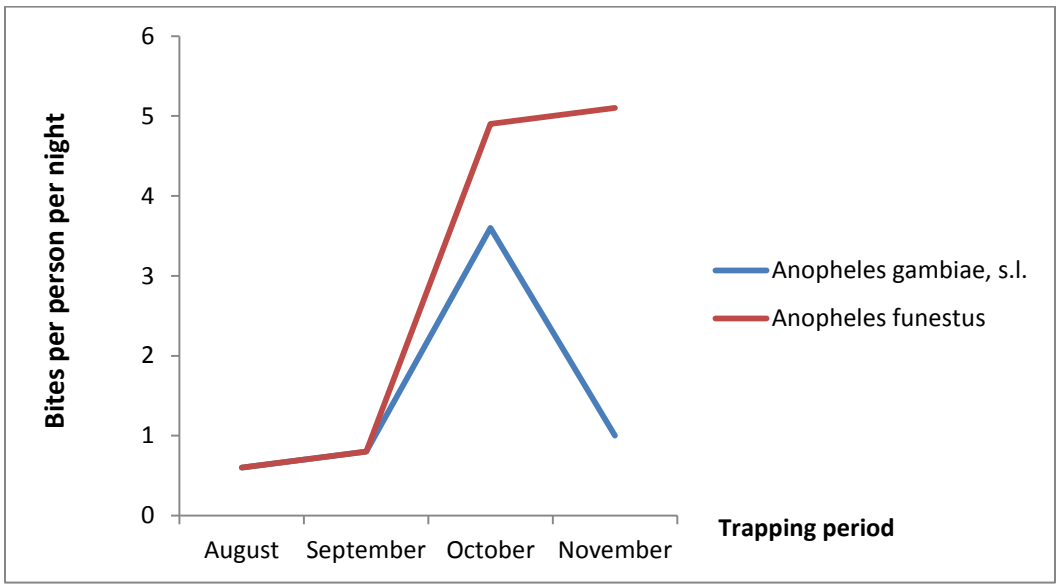


Figure 5: Human biting rate of *Anopheles gambiae* s.l. and *Anopheles funestus* s.l. in the Nioro district during the rainy season (sprayed and unsprayed villages combined)



3.2.2.2 *Ratio of indoor and outdoor biting measuring by human landing catch*

TABLE 8: ENDOPHAGY INDEX OF VECTORS IN IRS DISTRICTS

	August			September			October			November			Total		
	Ind.	Out.	**Endo.**	Ind.	Out.	**Endo.**	Ind.	Out.	**Endo.**	Ind.	Out.	**Endo.**	Ind.	Out.	**Endo.**
***An. gambiae* s.l.**															
Koungheul	12	8	**60%**	19	15	**56%**	23	22	**51%**	12	12	**50%**	66	57	**54%**
Koumpentoum	2	0	**100%**	4	1	**80%**	18	15	**55%**	4	4	**50%**	28	20	**58%**
Malem Hodar	8	1	**89%**	0	3	**0%**	8	15	**35%**	23	30	**43%**	39	49	**44%**
Nioro	8	15	**35%**	11	29	**28%**	84	75	**53%**	15	28	**35%**	118	147	**45%**
***An. funestus* s.l.**															
Nioro	7	18	**28%**	29	42	**41%**	96	120	**44%**	89	135	**40%**	221	315	**41%**

In all districts there was a similar proportion of indoor and outdoor biting by *An. gambiae* s.l. and for *An. funestus* s.l. in Nioro.

3.2.2.3 *Human biting rates in sprayed hot spots, unsprayed hot spots (external controls), and unsprayed low transmission villages (internal controls).*

The HBR was predicted to be far greater in the unsprayed hot spots (external controls) than in sprayed hot spots or unsprayed low transmission villages (internal controls). This expected pattern was observed in Koumpentoum where the mean biting rate of *An. gambiae* s.l. was 4.5 bites per person per night in the unsprayed hot spots, compared to 0.3 bites per person per night in the sprayed hot spots and 0.1 in the unsprayed low transmission villages. In the other three districts the differences were less clear. In Koungheul and Malem Hodar, the mean biting rate was low (<2 bites per person per night) every month regardless of whether the villages were hot spots, low transmission, unsprayed, or sprayed. In Nioro district there was a seasonal biting peak in October to the same magnitude regardless of whether villages were sprayed, unsprayed, hot spot or low transmission (Fig 8). *An. funestus* s.l. presented a higher density in October in sprayed areas and a peak in November in non-sprayed areas of Nioro district (Fig 9). Data was combined and grouped as either sprayed hot spot, internal control or external control (Fig 7) for all locations. The biting rates per month were similar for the sprayed hot spots and the internal controls throughout the monitoring period. The biting rate was consistently higher in the unsprayed external control sites.

Figure 6: ***Anopheles gambiae,*** **s.l. HBR in IRS districts compared to their controls.**

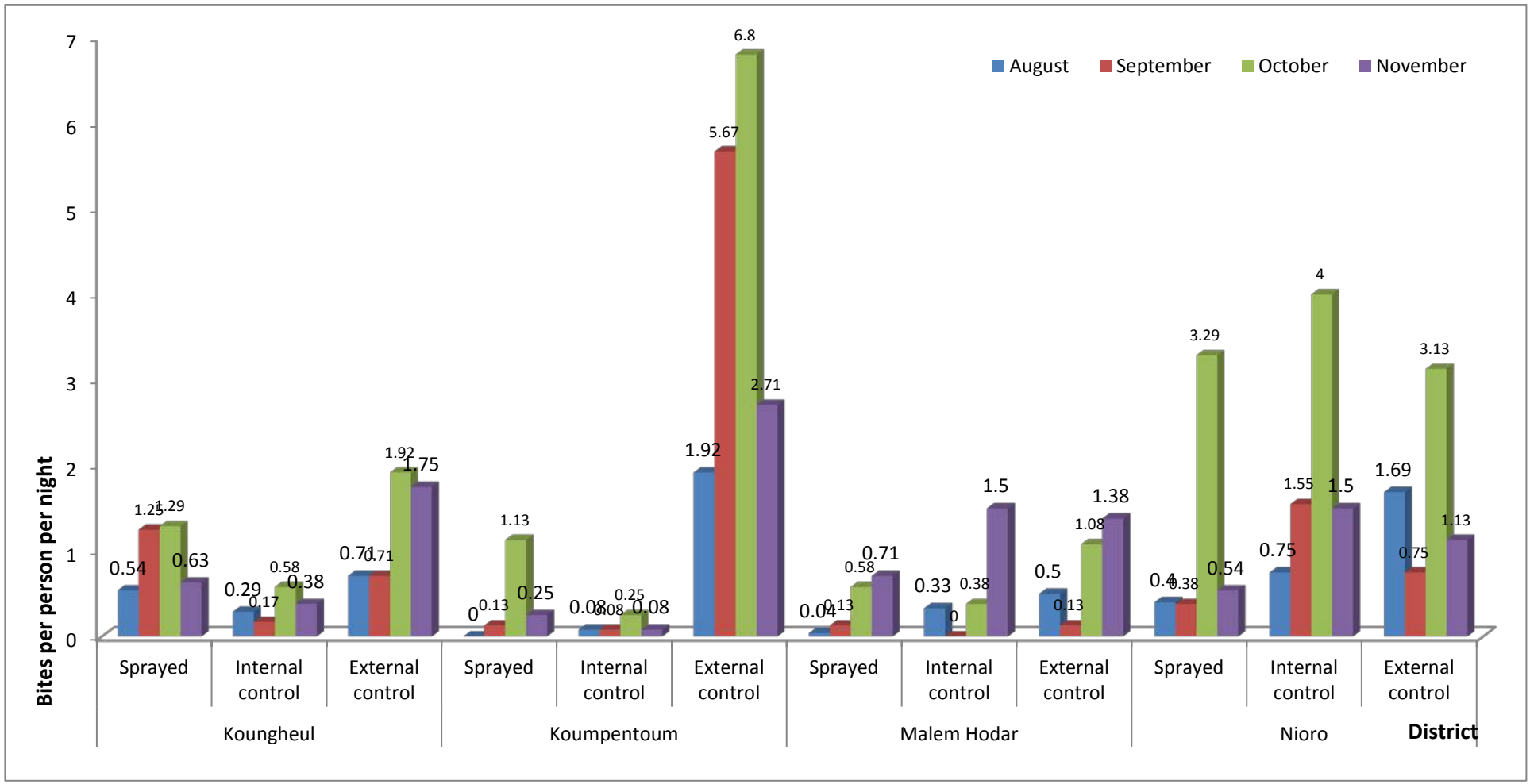


Figure 7: ***Anopheles gambiae*** **s.l. HBR in sprayed hot spots, unsprayed hot spots (external controls), and unsprayed low transmission villages (internal controls) combined for Koungheul, Koumpentoum, Malem Hodar, and Nioro.**

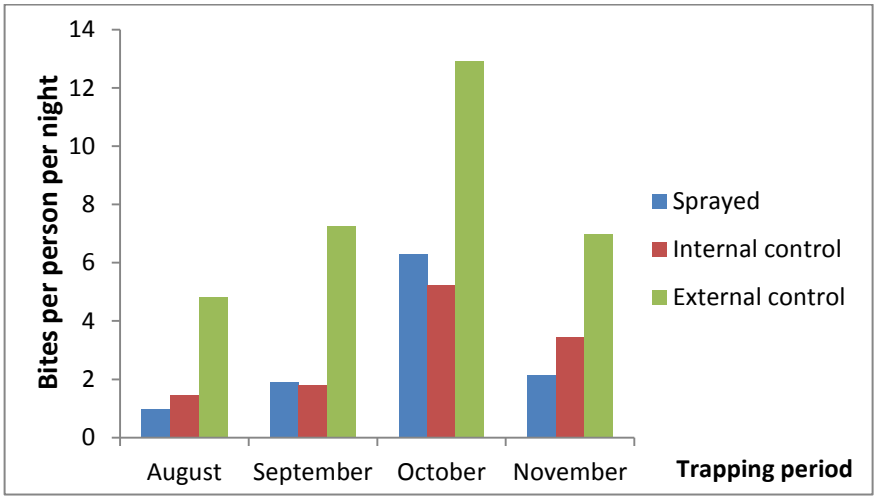


Figure 8: *Anopheles gambiae* s.l. HBR in Nioro district and its controls during rainy season.

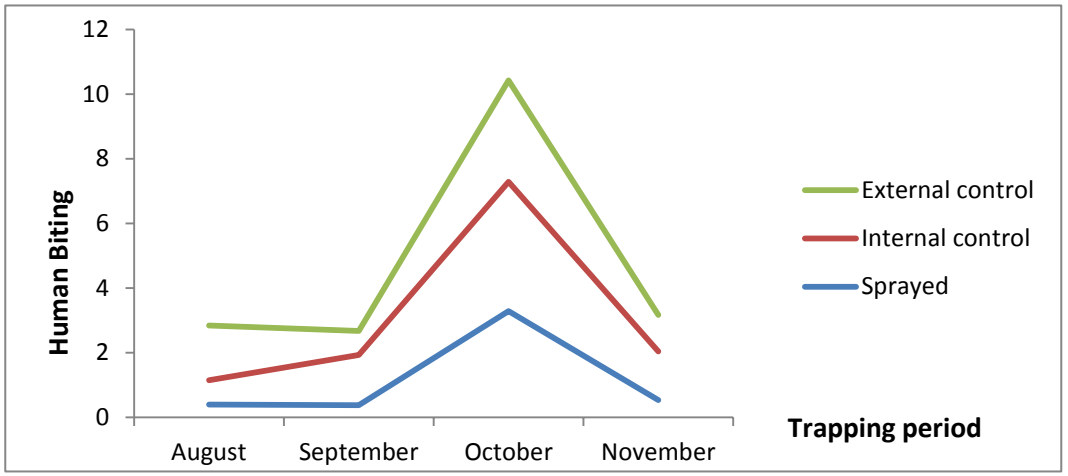
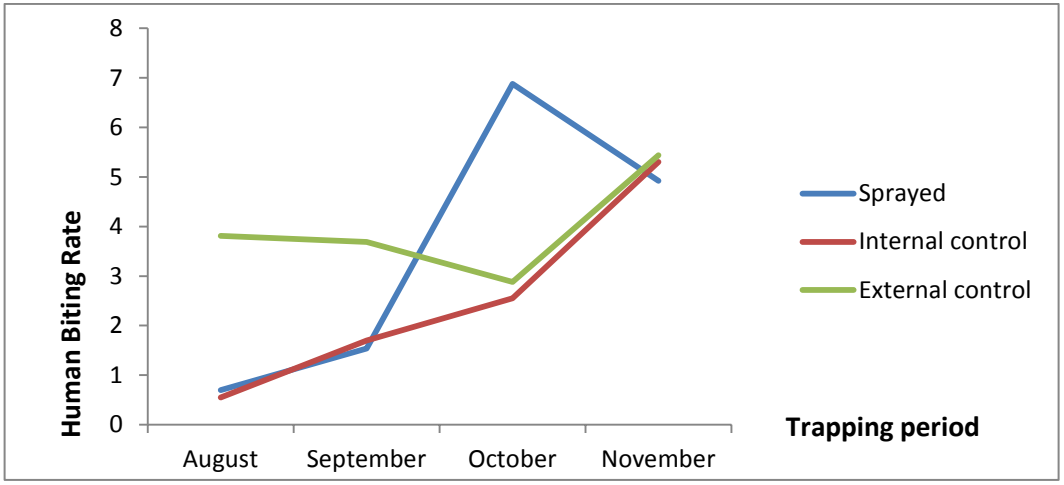


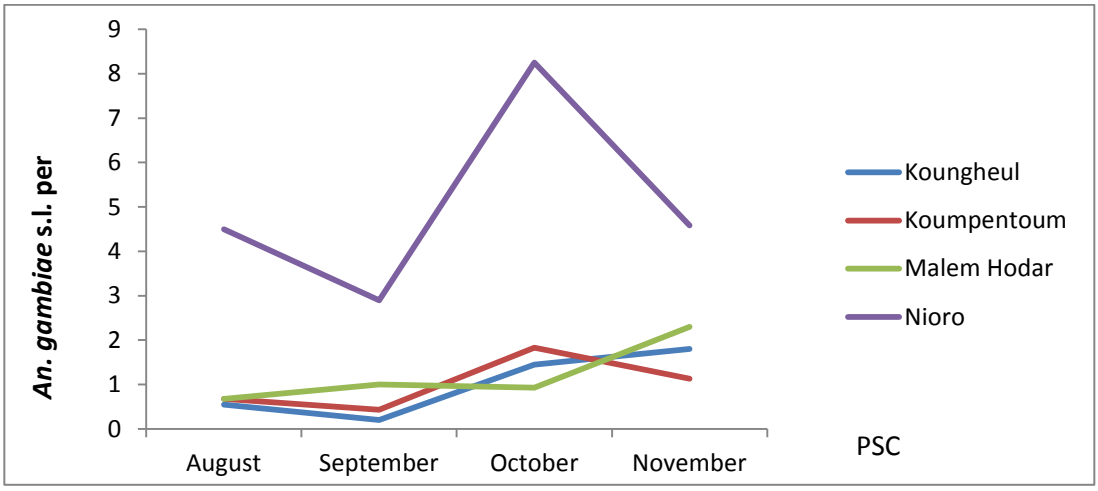
Figure 9: *Anopheles funestus* s.l. HBR in Nioro district and controls during the rainy season



3.2.3 INDOOR RESTING DENSITY

3.2.3.1 INDOOR RESTING DENSITY AT DISTRICT LEVEL BY PSC (SPRAYED AND UNSPRAYED VILLAGES COMBINED)

Figure 10: IRD of *Anopheles gambiae* s.l. in IRS districts during rainy season (including sprayed and unsprayed villages).



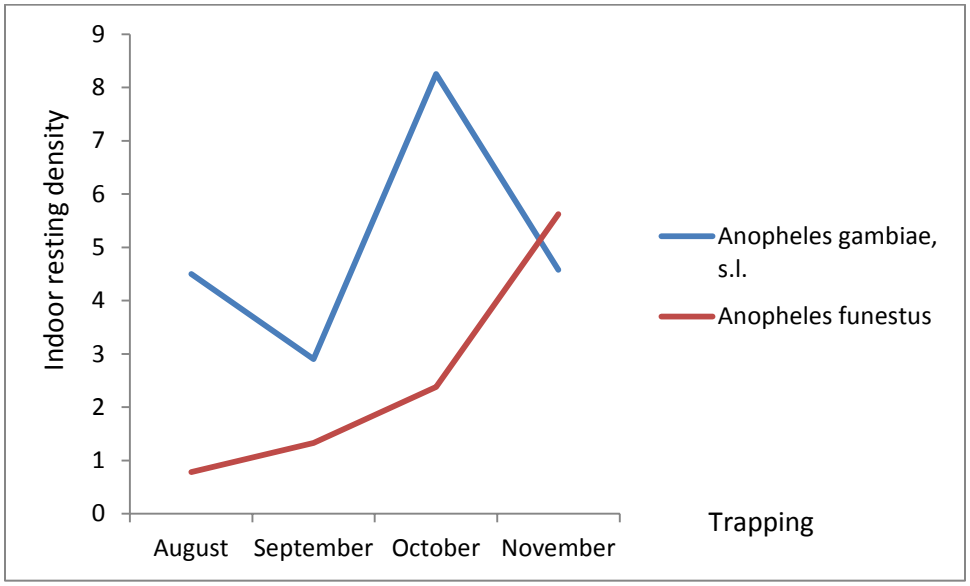
The IRD was considerably greater in Nioro than the other three districts, with a peak in October (Fig 10). The percentage of blood-fed females was generally 50-60 percent, with very few unfed and the remainder being half-gravid or gravid (Table 9).

TABLE 9: ABDOMINAL STATUS OF INDOOR RESTING *AN. GAMBIAE* S.L. IN IRS DISTRICTS (SPRAYED AND UNSPRAYED VILLAGES COMBINED).

District	Unfed	Blood-fed	Half gravid	Gravid	Total
Koungheul	4 (3%)	92 (58%)	46 (29%)	18 (11%)	160
Koumpentoum	8 (5%)	81 (50%)	15 (9%)	58 (36%)	162
Malem Hodar	16 (8%)	130 (66%)	29 (15%)	21 (11%)	196
Nioro	36 (4%)	507 (63%)	140 (17%)	126 (16%)	809

The IRD in Nioro was relatively high during the rainy season, especially in October with 8.3 females per room for *An. gambiae* s.l. and 2.4 for *An.funestus* s.l. This trend was reversed at the end of rainy season with an average of 5.6 *An. funestus* s.l. and 4.6 *An. gambiae* s.l. (fig. 11).

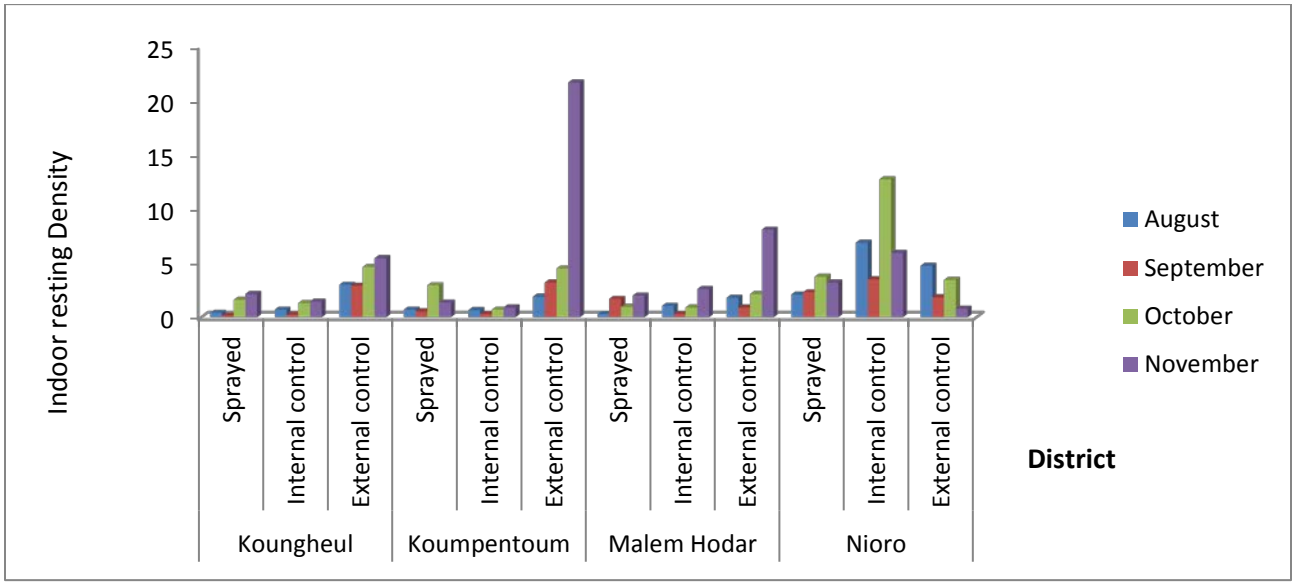
Figure 11: Comparison of *Anopheles gambiae,* s.l. and *Anopheles funestus* in the Nioro district during the rainy season.



3.2.3.2 *Indoor resting densities in sprayed hot spots, unsprayed hot spots (external controls) and unsprayed low transmission villages (internal controls)*

The indoor resting density of *An. gambiae* s.l. was greater in external control sites (unsprayed hot spots) except in Nioro District where it was higher in the internal control villages (unsprayed low transmission) (Fig. 12). Indoor resting densities were less than two *An. gambiae* s.l. per room in all sprayed villages except for Nioro where the mean was four per room per day.

Figure 12: *Anopheles gambiae* s.l. IRDs for sprayed hot spots, unsprayed hot spots and low transmission villages during the rainy season



3.2.4 PARITY RATE

3.2.4.1 PARITY RATE AT DISTRICT LEVEL

Lower parity rates were observed in sprayed villages of Koungheul and Malem Hodar districts than for unsprayed villages (Table 10), which may indicate that IRS reduced the mean life expectancy of *An. gambiae* s.l. There was no difference in parity rates between sprayed and unsprayed sites in Koumpentoum and Nioro. IRS may have been less effective in these two districts but other factors cannot be ruled out.

TABLE 10: *AN. GAMBIAE* S.L. PARITY RATE IN SPRAYED AREAS AND THEIR CONTROLS

District	Sprayed sites	Internal control	External control
Koungheul	52,7% (39/74)	72,2% (13/18)	81,5% (75/92)
Koumpentoum	83,3% (25/30)	77,8% (7/9)	79,6% (266/334)
Malem Hodar	43,7% (14/32)	76,1% (35/46)	64,7% (44/68)
Nioro	66,2% (49/74)	64,7% (66/102)	66,2% (94/142)

3.3 UNSPRAYED DISTRICTS

3.3.1 COMPOSITION OF SPECIES

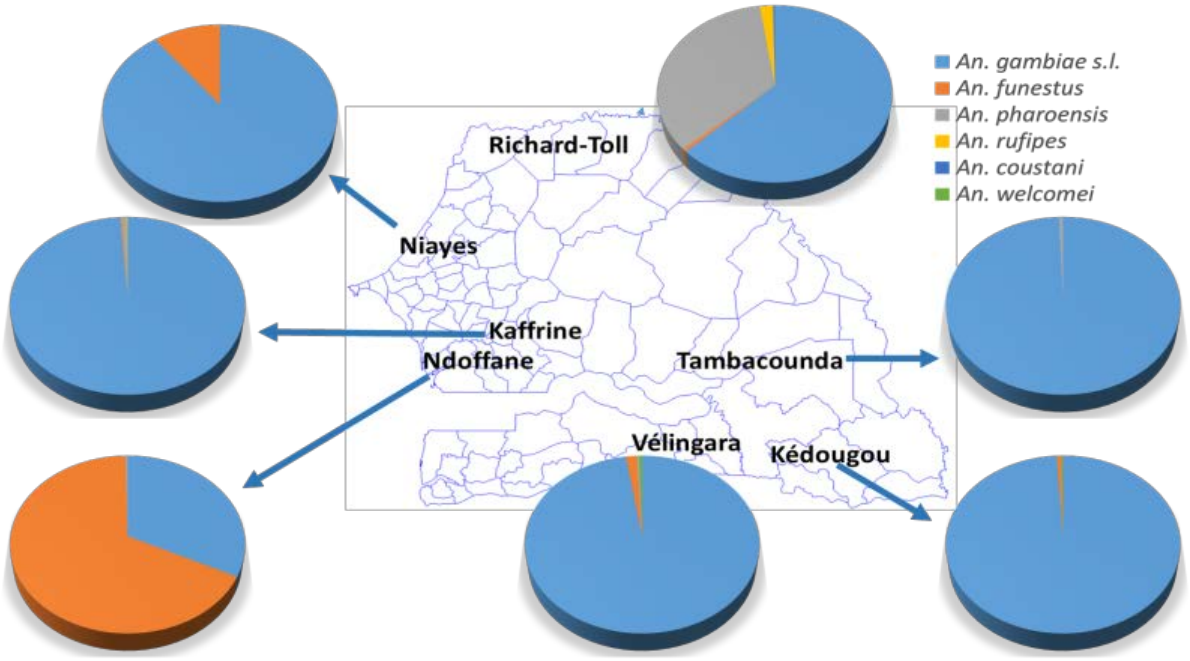
Six species of *Anopheles* were collected in non-IRS districts (Table 11). In all districts *An. gambiae* s.l. was predominant except in Ndoffane where *An. funestus* s.l. represented 67 percent of the collected *Anopheles*. *An. pharoensis* was collected in several sites, and accounted for 35 percent of *Anopheles* captured in Richard Toll (Fig 13).

TABLE 11: *ANOPHELES* SPECIES IN NON IRS DISTRICTS

Species*	Kedougou	Ndoffane	Niayes	Richard-Toll	Velingara	Kaffrine	Tambacounda
An. gambiae s.l.	2,397	379	122	472	596	616	1,078
An. funestus s.l.	06	771	14	4	10	1	0
An. pharoensis	0	1	0	261	2	5	7
An. rufipes	0	0	0	15	0	1	0
An. coustani	0	0	0	2	0	0	0
An. nili	2	0	0	0	3	0	0

* These are captured specimens (HLC bait) and collected by PSC

Fig13: *Anopheles* species collected in non IRS districts



3.3.2 HUMAN BITING RATE AND INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE* S.L.

The densities of human biting *An. gambiae* s.l. were higher in the south of the country (Kedougou, Velingara and Tambacounda): Fig. 13. In other districts, the HBR was lower and less than one bite/person/night; except in Ndoffane (which is the neighboring external control for Nioro). Despite the high biting rates in the south of the country, the indoor resting density was generally very low, except in Tambacounda (6.6 females per room) (Table 12 and Fig 14 and 15).

TABLE 12: HBR RATE AND IRD OF *ANOPHELES GAMBIAE* S.L. IN NON IRS DISTRICTS

Districts	HLC (HBR)						PSC (IRD)*					
	J	A	S	O	N	Mean	J	A	S	O	N	Mean
Kedougou	56,9	-	82,37	-	2,25	47,17	2,8	-	3,45	-	0,5	2,25
Ndoffane	2,19	1,69	0,75	3,12	1,12	1,78	1	4,75	1,85	3,45	0,95	2,37
Niayes	-	0	-	0,12	-	0,06	-	0,92	-	1,46	-	1,19
Richard-Toll	-	-	0,87	-	-	0,87	-	-	3,52	-	-	3,52
Velingara	-	15,29	-	6,45	-	10,88	-	2,8	-	0,9	-	1,85
Kaffrine	0,5	0,48	0,10	1,06	0,73	0,57	2,75	1,32	0,8	2,25	5,55	2,53
Tambacounda	0,46	1,91	5,67	6,79	2,7	3,5	1,55	1,9	3,2	4,5	21,7	6,57

HLC: Human Landing Catches **PSC**: Pyrethrum Spray Catches **HBR**: Human Bite Rate **IRD**: Indoor Resting Density

TABLE 13: ABDOMINAL STATUS OF *AN. GAMBIAE* S.L. COLLECTED BY PSC IN UNSPRAYED DISTRICTS

District	Unfed	Blood-fed	Half gravid	Gravid	Total
Niayes	5 (4%)	21 (18%)	26 (22%)	67 (56%)	119
Velingara	3 (4%)	43 (58%)	2 (3%)	26 (35%)	74
Kédougou	14 (11%)	97 (73%)	1 (1%)	21 (16%)	133

Fig. 14: Human biting rate variation in unsprayed districts

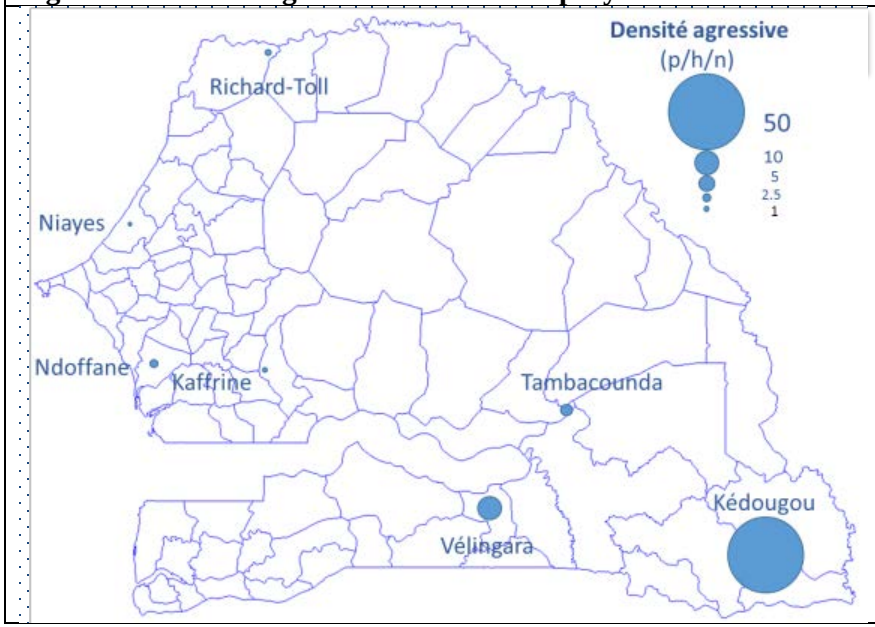
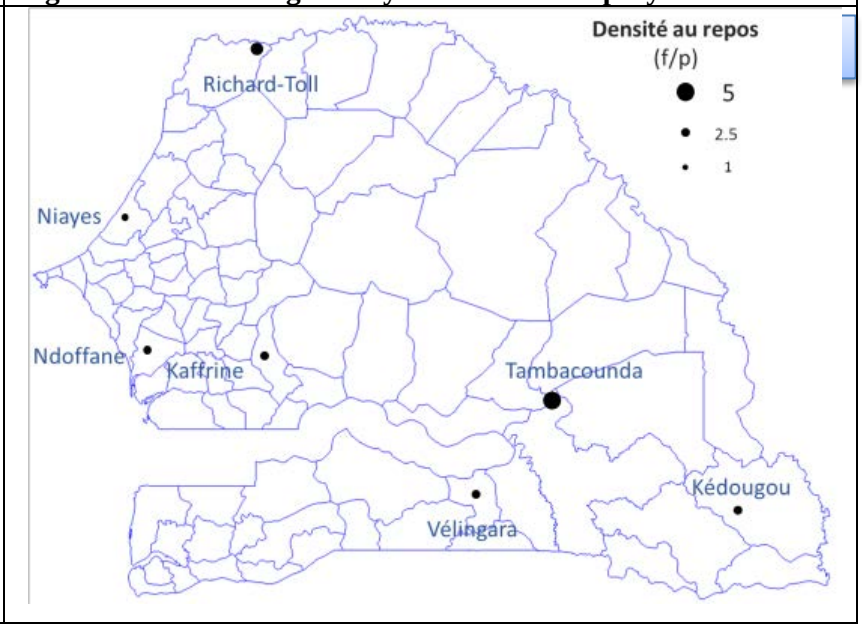


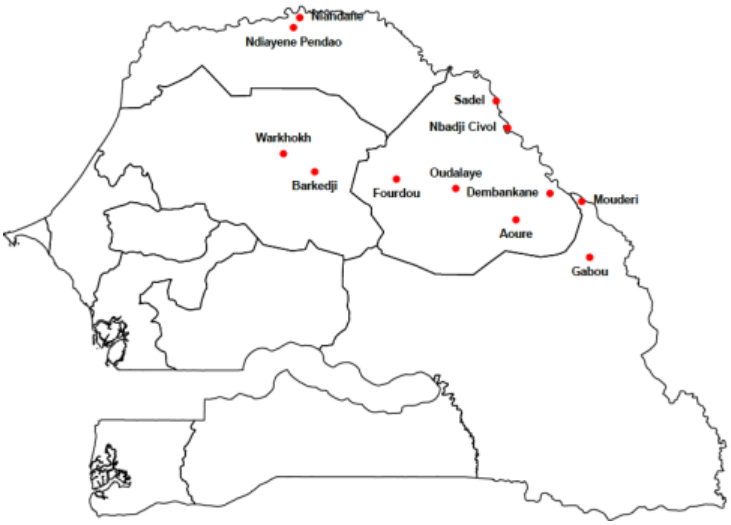
Fig. 15: Indoor resting density variation in unsprayed districts



3.4 DISTRICTS IN NORTH AND EAST-CENTRAL SENEGAL

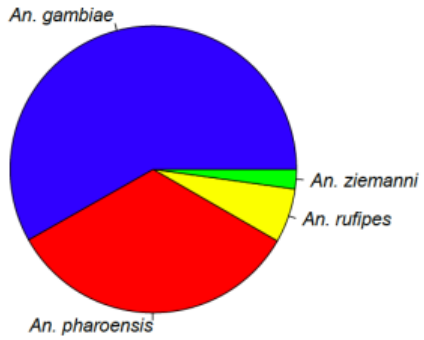
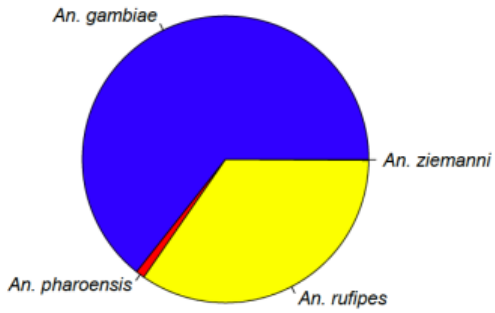
For sentinel sites in the Middle Senegal River Valley and Ferlo Region (Fig. 16), where the Pasteur Institute Entomological Division conducted entomological surveillance, results of mosquitoes collected during one survey during the rainy season are summarized in table 16 for resting density and Table 17 for biting *Anopheles*.

Fig16: Sentinel sites in the north and Ferlo Region



3.4.1 COMPOSITION OF SPECIES

An. gambiae s.l. was the main species present in both HLC and indoor resting catches. *An. pharoensis* was the second most common *Anopheles* species collected in HLC and *An. rufipes* in PSC (Figs. 17 and 18).

Fig. 17 Collected by Human Landing Catches	Fig. 18 Collected by Pyrethrum Spray Catches
	

3.4.2 HUMAN BITING RATES AND INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE* S.L.

HBRs were generally low in north and east-central Senegal, and the number of collected mosquitoes too few to give a reliable interpretation on the biting behavior (Table 14). Indoor resting collections were generally higher with a maximum of 34.3 *An. gambiae* s.l. collected resting indoors in Matam (Table 15).

TABLE 14: COLLECTION OF BITING MOSQUITOES (HUMAN-LANDING COLLECTIONS) IN SEPTEMBER - OCTOBER

Sites	Number	*An. gambiae* s.l.				*An. pharoensis*				*An. rufipes*				*An. ziemanni*			
	Human/	Outdoor		Indoor		Outdoor		Indoor		Outdoor		Indoor		Outdoor		Indoor	
	Night	N	HBR	N	HBR	N	HBR	N	HBR	N	HBR	N	HBR	N	HBR	N	HBR
Barkedji	6	4	0.67	2	0.33	0	0	0	0	0	0	0	0	0	0	0	0
Warkhokh	6	4	0.67	2	0.33	0	0	0	0	0	0	1	0.17	0	0	0	0
Dembancane	6	8	1.33	8	1.33	4	0.67	1	0.17	1	0.17	0	0	1	0.17	0	0
Aoure	6	3	0.5	2	0.33	0	0	0	0	0	0	0	0	0	0	0	0
Fourdou	6	6	1	4	0.67	0	0	0	0	0	0	0	0	0	0	0	0
Oudalaye	6	1	0.17	5	0.83	1	0.17	0	0	0	0	0	0	0	0	0	0
Ndiayene-Pendao	6	8	1.33	5	0.83	6	1	4	0.67	3	0.5	0	0	10	1.67	8	1.33
Niandane	6	7	1.17	6	1	2	0.33	2	0.33	0	0	1	0.17	4	0.67	1	0.17
Sadel	6	1	0.17	3	0.5	1	0.17	1	0.17	0	0	0	0	0	0	0	0
Nabadji Civol	6	3	0.5	1	0.17	0	0	1	0.17	0	0	1	0.17	0	0	0	0
Gabou	6	8	1.33	13	2.17	0	0	1	0.17	0	0	0	0	0	0	0	0
Moudery	6	1	0.17	3	0.5	0	0	0	0	0	0	2	0.33	0	0	0	0

N=number. HBR=Human biting rate

TABLE 15: COLLECTION OF RESTING MOSQUITOES IN HUMAN DWELLINGS (PYRETHRUM SPRAY COLLECTIONS) IN SEPTEMBER - OCTOBER

Sites	Districts	Number	*An. gambiae* s.l.		*An. pharoensis*		*An. rufipes*		*An. ziemanni*	
		of rooms	N	IRD	N	IRD	N	IRD	N	IRD
Barkedji	Linguère	10	42	4.2	1	0.1	1	0.1	0	0
Warkhokh	Linguère	10	20	2	0	0	0	0	0	0
Dembancane	Kanel	10	82	8.2	0	0	86	8.6	1	0.1
Aoure	Kanel	10	1	0.1	0	0	0	0	0	0
Fourdou	Ranérou	10	28	2.8	0	0	0	0	0	0
Oudalaye	Ranérou	10	74	7.4	0	0	4	0.4	0	0
Ndiayene-Pendao	Podor	10	91	9.1	0	0	9	0.9	0	0
Niandane	Podor	10	53	5.3	0	0	1	0.1	0	0
Sadel	Matam	10	343	34.3	0	0	281	28.1	0	0
Nabadji Civol	Matam	10	197	19.7	1	0.1	105	10.5	0	0
Gabou	Bakel	10	127	12.7	0	0	0	0	0	0
Moudery	Bakel	10	60	6	0	0	66	6.6	0	0

N=number. IRD= Indoor resting density

3.5 PERFORMANCE OF METHODS FOR COLLECTING ADULT MOSQUITOES FROM *ANOPHELES GAMBIAE S.L*

The project compared HLC and PSC respectively to CDC Light Trap and Propkopack collections in four districts. These districts were selected according their geographical position: Richard Toll (north), Kedougou (south) and two sites in the central area (Ndoffane and Nioro). This study showed that the HBR was significantly higher with HLC than CDC light trap in all districts. The same observations were noted with the PSC compared to the Prokopack (Figs 17 and 18). Therefore, in 2017, the project will conduct only HLC and PSC.

Figure 17 : Comparison of Human Biting Rate between HLC and CDC light Trap

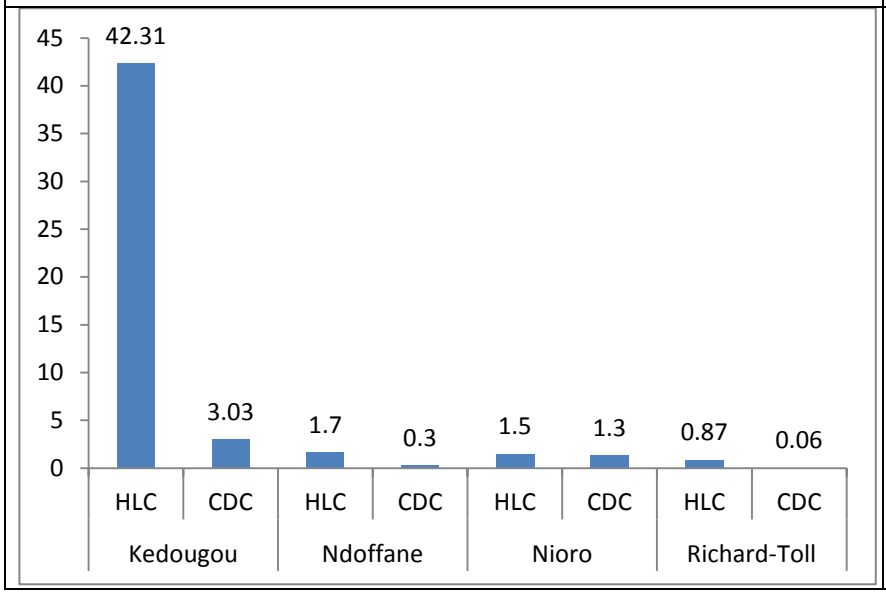
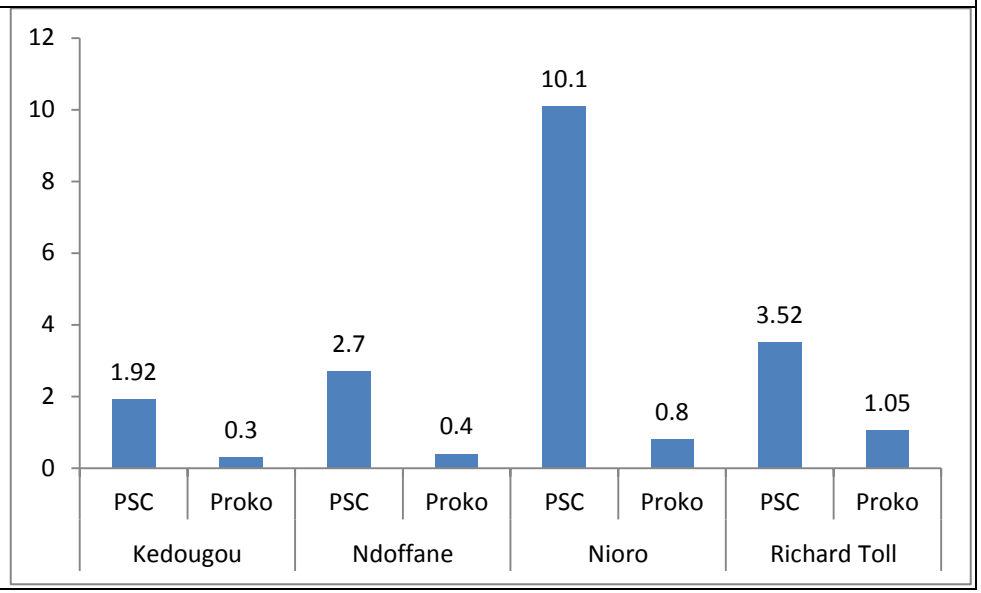


Figure 18 : Comparison of Indoor Resting Density between PSC and Prokopack



3.6 SUSCEPTIBILITY TESTS OF MALARIA VECTORS TO INSECTICIDES

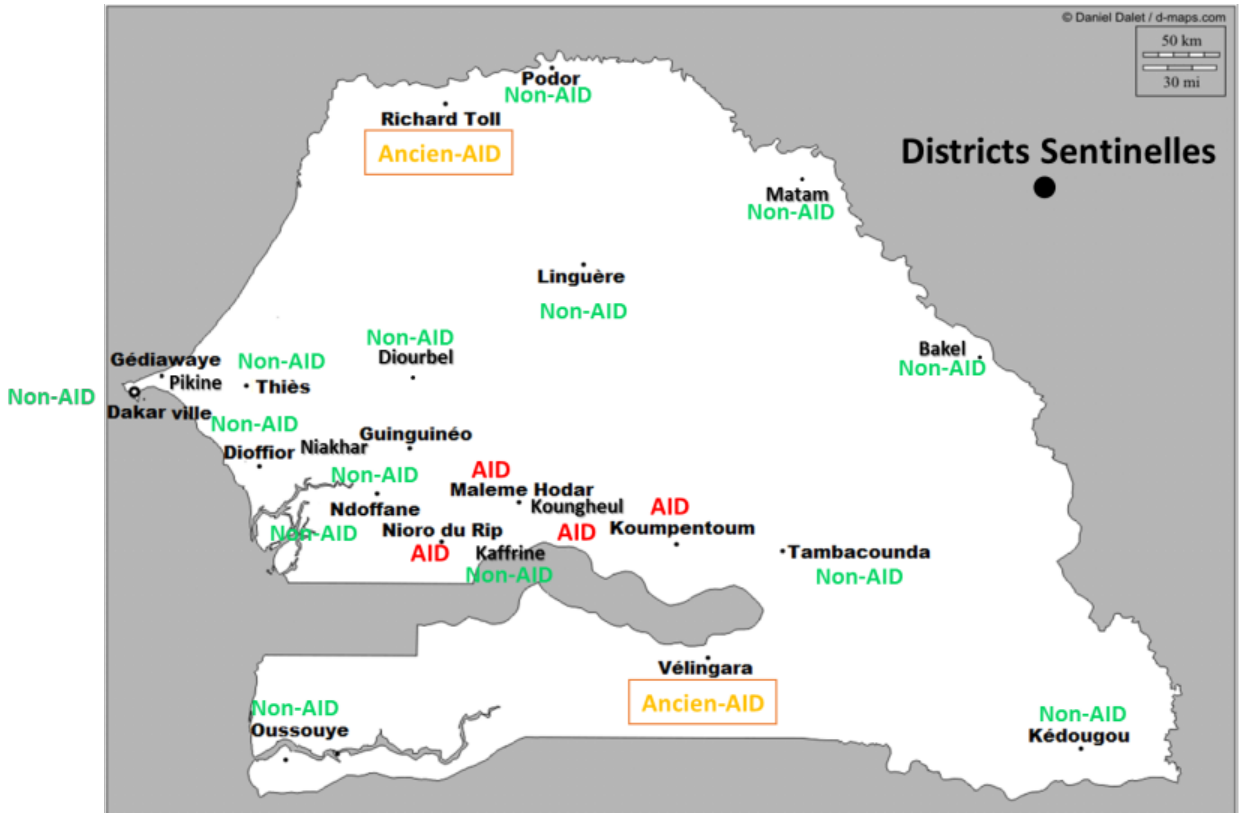
3.6.1 WHO SUSCEPTIBILITY TESTS WITH IMPREGNATED PAPERS

For each insecticide, the project tested at least 100 mosquitoes in four replicates of 25. The mortalities of the exposed samples were validated by use of untreated controls. The basis for interpreting the results is presented in the table below (WHO, 2013).

Status	Interpretation threshold	Additional analysis threshold	Observations
Susceptible	98-100%	98-100%	Confirmed susceptibility
Resistant	Less than 98%	90-98%	Resistance to be confirmed
		Less than 90%	Confirmed resistance

Susceptibly tests were done in various IRS and unsprayed districts (fig. 19).

Figure 19: Selected districts for susceptibly tests



The results of WHO tube assays (Table 19) showed resistance of *Anopheles gambiae* s.l. to all three pyrethroid insecticides tested in all districts, except in rare cases where susceptibility was recorded in Niakhar (deltamethrin and lambda-cyhalothrin) and in Koungheul (Permethrin). For organophosphates (pirimiphos methyl 0.25%), the vector populations are fully susceptible, including in IRS districts. *An. gambiae* also showed susceptibility to carbamates (bendiocarb) in several districts but resistance was noted in Dakar (80%) and its suburb (27%) and possible resistance in Niayes (96%), Diourbel (94%) and Kedougou (93%).

TABLE 16: SUSCEPTIBILITY CYLINDER TEST RESULTS FOR *ANOPHELES GAMBIAE* S. L. 24 HOURS AFTER ONE HOUR EXPOSURE TO WHO DIAGNOSTIC DOSE OF FIVE INSECTICIDES.

Districts	Deltamethrin 0.05%			Lambdacyhalothin 0.05%			Permethrin 0.75%			Pirimiphos-methyl 0.25%			Bendiocarb 0.1%		
	No tested	Dead 24h	% Mortality	No tested	Death 24h	%	No tested	Death 24h	%	No tested	Death 24h	%	No tested	Death 24h	%
	IRS districts														
Koungheul	101	83	**82**	107	79	**74**	102	100	**98***	125	125	**100***	107	107	**100***
Koumpentoum	100	94	**94**	103	68	**62***	101	93	**91***	103	103	**100**	105	103	**98**
Malem Hodar	107	96	**90**	107	104	**97**	123	105	**85**	102	102	**100**	105	105	**100**
Nioro	111	72	**62***	133	99	**72***	106	76	**69***	142	142	**100**	123	123	**100**
	IRS District controls														
Ndoffane	110	80	**71***	134	67	**50**	113	81	**70***	124	124	**100**	105	105	**100**
Kaffrine	101	78	**77**	124	88	**70***	101	60	**59**	100	100	**100**	123	123	**100**
Tambacounda	211	129	**61**	239	170	**71***	234	173	**74**	209	208	**99,5***	215	213	**99***
	Nothern districts and Ferlo														
Richard Toll	119	95	**80**	120	57	**48***	123	89	**72**	107	107	**100**	107	107	**100**
Podor	113	93	**84**	-	-	-	-	-	-	-	-	-	-	-	-
Kanel	108	91	**84**	-	-	-	-	-	-	-	-	-	-	-	-
Bakel	103	86	**83**	107	91	**85**	-	-	-	-	-	-	-	-	-
Linguere	106	92	**87**	-	-	-	-	-	-	-	-	-	-	-	-
Ranerou	103	87	**85**	-	-	-	-	-	-	-	-	-	-	-	-
	Dakar and its suburbs														
Niayes	102	78	**77**	114	75	**66**	101	97	**96**	102	102	**100**	100	96	**96**
Pikine	113	61	**54**	110	30	**27**	127	19	**15**	100	100	**100**	123	33	**27**
Rufisque	246	108	**44**	354	55	**16**	234	74	**31**	-	-	-	-	-	-
Campus UCAD	100	39	**36***	109	50	**46**	101	28	**25***	100	100	**100**	122	97	**80**
Colobane (Dkr)	102	100	**98**	100	95	**95**	103	75	**73**	-	-	-	-	-	-
	Central districts														
Niakhar	106	105	**99**	104	103	**99**	103	85	**83**	105	105	**100**	110	110	**100**
Guinguinéo	104	78	**75**	103	88	**85***	108	80	**74**	114	114	**100**	103	103	**100**
Diourbel	108	97	**89***	112	91	**80***	107	91	**84***	-	-	-	108	102	**94**
	Southern districts														
Velingara	121	103	83*	128	74	**54***	123	103	**82***	130	130	**100***	105	105	**100**
Kedougou	120	76	61*	116	49	**36***	124	57	**43***	123	123	**100***	113	105	**93***

*: Corrected mortality

3.6.2 SUSCEPTIBILITY WITH CDC BOTTLE TEST

In the work plan resistance intensity assays were planned using ×1, ×2, ×5, ×10 times the diagnostic dose of a pyrethroid and a carbamate in selected sites of high resistance. As in the WHO susceptible test, CDC bottle tests showed resistance to Bendiocarb in Kedougou (87.7%) and the in suburb of Dakar (94.3% in Pikine). Results for ×2, ×5, ×10 times the diagnostic doses are being entered and will be included in a supplementary report in February 2017.

TABLE 17: SUSCEPTIBILITY STATUS OF *AN. GAMBIAE* S.L. WITH CDC BOTTLE TESTS

Districts	CDC Bottle test Deltamethrin 12.5µl/Btl			WHO test Deltamethrin 12.5µl/Btl			CDC Bottle test Bendiocarb 12µl/Btl			WHO test Bendiocarb 12µl/Btl		
	Tested	Dead 24h	% Mortality	Tested	Dead 24h	% Mortality	Tested	Dead 24h	% Mortality	Tested	Dead 24h	% Mortality
Kaffrine	103	98	**95**	101	78	**77**	101	101	**100**	123	123	**100**
Nioro	117	116	**99**	11	72	62	-	-	-	123	123	**100**
Koungheul	108	96	**88***	101	83	**82**	100	100	**100**	107	107	**100**
Koumpentoum	103	100	**97***	100	94	**94**	114	114	**100**	105	103	**98**
Tambacounda#	244	213	**87**	211	129	**61**	108	107	**99**	215	213	**99**
Guinguineo	108	9	**92**	104	78	**75**	109	2	**98**	103	103	**100**
Richard Toll	102	75	**74**	119	95	80	-	-	-	107	107	**100**
Pikine	215	153	**71**				210	198	**94**			
Colobane (Dkr)	217	203	**94**	102	100	**98**	195	194	**99.5**			
Kédougou	113	13	**12**	120	76	**61**	114	100	**88**	113	105	**93**

4. CONCLUSION

This report presents results monitoring the residual effectiveness of the spray campaign and entomological surveillance in Senegal during the rainy season (July-November 2016). In general, pirimiphos-methyl IRS lasted for between two to five months for mud and concrete walls (according to World Health Organization (WHO) criteria of >80% mortality). Residual performance was shortest in Malem Hodar where mortality was only >80% for 1 month after spraying, although mortality remained >70% after 3 months on mud and cement walls. Elsewhere, mortality was >80% on cement walls for 4-5 months. Strictly following WHO criteria, residual performance was 2-4 months on mud walls, however in most sites mortality remained >70% for 5 months. The project must conduct further investigations to understand the relatively short residual performance in Senegal, particularly in Malem Hodar. Mud samples from a spray district in Senegal are currently being tested for physical and chemical composition at ACS Soil Testing Facility in the UK and results will be available in February. Further bioassay testing will be conducted at the LITE facility in Liverpool to compare residual duration of different soil types from Burkina Faso, Mali, Benin, and Cote d'Ivoire to generate better understanding of the factors that result in short residual duration of Actellic CS in some locations.

WHO cylinder tests indicated full susceptibility of wild *An. gambiae* s.l. to pirimiphos-methyl (0.25%) in all 15 sites tested, including all four IRS districts. Resistance to bendiocarb (0.1%) was only recorded in the Dakar suburbs of Pikine and UCAD campus, with possible resistance in Kedougou and Diourbel and full susceptibility recorded in IRS districts. Therefore, rotation of bendiocarb and pirimiphos-methyl for IRS could be considered as part of a resistance management plan, if bendiocarb is considered to be sufficiently long-lasting.

In Koungheul and Malem Hodar the mean biting rate was low (<2 bites per person per night) every month regardless of whether the villages were hot spots, low transmission, unsprayed, or sprayed. In Nioro district there was a seasonal biting peak of *An. gambiae* s.l. and *An. funestus* s.l. in October (two months after spraying) to the same magnitude regardless of whether villages were sprayed, unsprayed, hot spot or low transmission. Parity dissections indicated that IRS may have shortened *An. gambiae* s.l. life expectancy in two of four IRS districts, but not the two districts with the longest residual efficacy. The entomology data does not convincingly demonstrate that IRS is having a substantial impact on the local malaria vector population. Therefore, 2016 malaria case data from IRS health districts and unsprayed control villages should be analyzed together with entomology data to determine whether the current strategy of hot spot spraying is effective in Senegal.

In general, the population density of malaria vectors was low in the districts of North and Central Senegal. The biting rates were considerably higher in the south of the country in Velingara, Tambacounda and Kedougou. In 2017 there will be an operational research component included in the work plan to better understand vector behavior in Southern Senegal with a view to improved vector control in future.

ANNEXES

Annex 1: COLLECT FORM FOR CDC LIGHT TRAP

District: **Locality**: **Date** : ……..… / ……..… / ……

Month	**Nights**	**Compound 1** : **Room 1** : **Status** :	**Compound 2 :** **Room 2** : **Status**:	**Compound 3** : **Room** 3 : **Status** :
July	1	HLC	CDC-LT	HLC T &CDC-LT
	2	HLC T &CDC-LT	HLC	CDC-LT
August	3	CDC-LT	HLC T &CDC-LT	HLC
	4	HLC	CDC-LT	HLC T &CDC-LT
September	5	HLC T &CDC-LT	HLC	CDC-LT
	6	CDC-LT	HLC T &CDC-LT	HLC
October	7	HLC	CDC-LT	HLC T &CDC-LT
	8	HLC T &CDC-LT	HLC	CDC-LT
November	9	CDC-LT	HLC T &CDC-LT	HLC
	10	HLC	CDC-LT	HLC T &CDC-LT
December	11	HLC T &CDC-LT	HLC	CDC-LT
	12	CDC-LT	HLC T &CDC-LT	HLC

Annex 2: SPECIES COMPOSITION ACCORDING TO SAMPLING METHOD DURING RAINY SEASON (Koungheul)

Months	Species	HLC			RC	Total
		Indoor	Outdoor	Total		
August	*An. gambiae s.l.*	**12**	**8**	**20**	**22**	**42**
	An. funestus	0	0	0	0	0
	An. pharoensis	0	2	2	0	2
September	*An. gambiae s.l.*	**19**	**15**	**34**	**8**	**42**
	An. funestus	0	0	0	0	0
	An. pharoensis	0	3	3	0	3
October	*An. gambiae s.l.*	**23**	**22**	**45**	**58**	**103**
	An. funestus	0	0	0	0	0
	An. pharoensis	1	0	1	0	1
November	*An. gambiae s.l.*	**12**	**12**	**24**	**72**	**96**
	An. funestus	0	0	0	0	0
	An. pharoensis	0	0	0	0	0
	An. rufipes	0	0	0	8	8
Total	*An. gambiae s.l.*	**66**	**57**	**123**	**160**	**283**
	An. funestus	0	0	0	0	0
	An. pharoensis	1	5	6	0	6
	An. rufipes	0	0	0	8	8

HLC: Human Landing Catches **RC: Resting Collect**

Annex 3: SPECIES COMPOSITION ACCORDING TO SAMPLING METHOD DURING RAINY SEASON (Koumpentoum)

Month	Species	HLC			RC	Total
		Indoor	Indoor	Indoor		
August	*An. Gambiae* s.l.	**2**	**0**	**2**	**27**	**29**
	An. funestus	0	0	0	1	1
September	*An. Gambiae* s.l.	**4**	**1**	**5**	**17**	**22**
	An. funestus	0	0	0	0	0
October	*An. Gambiae* s.l.	**18**	**15**	**33**	**73**	**106**
	An. funestus	0	0	0	0	0
	An. pharoensis	0	1	1	0	1
	An. rufipes	4	0	4	5	9
	An. coustani	0	2	2	0	2
November	*An. Gambiae* s.l.	**4**	**4**	**8**	**45**	**53**
	An. funestus	0	0	0	0	0
	An. rufipes	0	0	0	11	11
Total	*An. gambiae* s.l.	**28**	**20**	**48**	**162**	**210**
	An. funestus	0	0	0	1	1
	An. pharoensis	0	1	1	0	1
	An. rufipes	4	0	4	16	20
	An. coustani	0	2	2	0	2

Annex 4: SPECIES COMPOSITION ACCORDING TO SAMPLING METHOD DURING RAINY SEASON (Malem Hodar)

Mois	Espèces	HLC			RC	Total
		Indoor	Indoor	Indoor		
August	*An. gambiae* s.l.	8	1	9	27	36
	An. funestus	0	0	0	0	0
	An. pharoensis	0	0	0	0	0
September	*An. gambiae* s.l.	0	3	3	40	43
	An. funestus	0	0	0	0	0
	An. pharoensis	0	0	0	0	0
October	*An. gambiae* s.l.	8	15	23	37	60
	An. funestus	0	0	0	0	0
	An. pharoensis	1	0	1	0	1
	An rufipes	0	0	0	4	4
November	*An. gambiae* s.l.	23	30	53	92	145
	An. funestus	0	0	0	0	0
	An. pharoensis	0	0	0	0	0
	An rufipes	0	0	0	11	11
Total	***An. gambiae s.l.***	**39**	**49**	**88**	**196**	**284**
	An. funestus	0	0	0	0	0
	An. pharoensis	1	0	1	0	1
	An rufipes	0	0	0	15	15

Annex 5: SPECIES COMPOSITION ACCORDING TO SAMPLING METHOD DURING RAINY SEASON (Nioro)

Month	Espèces	HLC			CDC LT			RC PSC	RC Prokopack
		Indoor	Outdoor	Total	Indoor	Outdoor	Total		
August	*An. gambiae* s.l.	8	15	23	5	2	7	180	1
	An. funestus	7	18	25	4	2	6	31	1
	An coustani	0	0	0	0	6	6	0	0
	An. rufipes	0	0	0	4	5	9	17	26
	An welcomei	0	0	0	1	1	2	0	0
September	*An. gambiae* s.l.	11	29	40	26	4	30	116	4
	An. funestus	29	42	71	22	10	32	53	13
	An. pharoensis	0	0	0	0	0	0	0	0
	An coustani	4	12	16	24	3	27	1	43
	An rufipes	0	0	0	0	0	0	5	0
October	*An. gambiae* s.l.	84	75	159	8	5	13	330	15
	An. funestus	96	120	216	9	14	23	95	30
	An. pharoensis	0	0	0	1	0	1	0	0
	An coustani	3	1	4	27	13	50	0	0
	An rufipes	0	0	0	0	0	0	11	6
	An. wellcomei	7	0	7	0	0	0	0	0
November	*An. gambiae* s.l.	15	28	43	5	2	7	183	12
	An. funestus	89	135	224	43	24	67	225	59
	An. pharoensis	0	1	1	0	0	0	0	0
	An coustani	4	12	16	24	3	27	0	0
Total	*An. gambiae* s.l.	118	147	265	44	13	57	809	32
	An. funestus	221	315	536	78	50	128	404	103
	An. pharoensis	0	1	1	1	0	1	0	0
	An coustani	11	25	36	75	25	110	1	43
	An. rufipes	0	0	0	4	5	9	33	32
	An welcomei	7	0	7	1	1	2	0	0

Annex 6: HUMAN BITING RATE AND INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE* S.L. FEMALES IN KOUNGHEUL, KOUMPENTOUM AND MALEM HODDAR

Districts		HLC (HBR)															RC (IRD)				
		Indoor					Outdoor					Total									
		A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T
Koungheul	HN/Room	24	24	24	24	96	24	24	24	24	96	48	48	48	48	192	40	40	40	40	160
	Number	12	19	23	12	66	8	15	22	12	57	20	34	45	24	123	22	8	58	72	160
	HBR/IRD	**0.50**	**0.80**	**0.96**	**0.50**	**0.70**	**0.33**	**0.63**	**0.92**	**0.50**	**0.60**	**0.42**	**0.71**	**0.94**	**0.50**	**0.64**	**0.55**	**0.20**	**1.45**	**1.80**	**1**
Koumpentoum	HN/Room	24	24	24	24	96	24	24	24	24	96	48	48	48	48	192	40	40	40	40	160
	Number	2	4	18	4	28	0	1	15	4	20	2	5	33	8	48	27	17	73	45	162
	HBR/IRD	**0,08**	**0,17**	**0,75**	**0,17**	**0,29**	**0**	**0,04**	**0,63**	**0,17**	**0,21**	**0,04**	**0,10**	**0,69**	**0,17**	**0,25**	**0,68**	**0,43**	**1,83**	**1,13**	**1,01**
Malem Hodar	HN/Room	24	24	24	24	96	24	24	24	24	96	48	48	48	48	192	40	40	40	40	160
	Number	8	0	8	23	39	1	3	15	30	49	9	3	23	53	88	27	40	37	92	196
	HBR/IRD	**0,33**	**0**	**0,33**	**0,96**	**0,41**	**0,04**	**0,13**	**0,63**	**1,25**	**0,51**	**0,2**	**0,06**	**0,48**	**1,10**	**0,46**	**0,68**	**1,00**	**0,93**	**2,30**	**1,23**

HLC: Human Landing Catches; HBR : Human Biting Rate ; HN : Human/Night RC : Resting Collect IRD : Indoor Resting Density
A, S, O, N E et T: August, September, October, November and Total

Annex7: HUMAN BITING RATE AND INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE* S.L. FEMALES IN NIORO

	HLC															CDC LT													
	Indoor					Outdoor					Total					Indoor					Outdoor					Total				
	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T
HN	20	26	22	22	90	20	26	22	22	90	40	52	44	44	180	10	4	4	4	22	10	4	4	4	22	20	8	8	8	44
Number	8	11	84	15	118	15	29	75	28	147	23	40	159	43	265	5	26	8	5	44	2	4	5	2	13	7	30	13	7	57
TAH	**0,4**	**0,4**	**3,8**	**0,7**	**1,3**	**0,8**	**1,1**	**3,4**	**1,3**	**1,6**	**0,6**	**0,8**	**3,6**	**1**	**1,5**	**0,5**	**6,5**	**2**	**1,3**	**2**	**0,2**	**1**	**1,3**	**0,5**	**0,6**	**0,4**	**3,8**	**1,6**	**0,9**	**1,3**

Annex 8: HUMAN BITING RATE AND INDOOR RESTING DENSITY OF *ANOPHELES FUNESTUS* S.L. FEMALES IN NIORO

	HLC															CDC LT													
	Indoor					Outdoor					Indoor					Outdoor					Indoor					Total				
	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T
HN	20	26	22	22	90	20	26	22	22	90	40	52	44	44	180	10	4	4	4	22	10	4	4	4	22	20	8	8	8	44
Number	7	29	96	89	221	18	42	120	135	315	23	40	216	224	536	4	22	9	43	78	2	10	14	24	50	6	32	23	67	128
HBR	**0,4**	**1,1**	**4,4**	**4**	**2,5**	**0,9**	**1,6**	**5,5**	**6,1**	**3,5**	**0,6**	**0,8**	**4,9**	**5,1**	**3**	**0,4**	**5,5**	**2,3**	**10,8**	**3,5**	**0,2**	**2,5**	**3,5**	**6**	**2,3**	**0,3**	**4**	**2,9**	**8,4**	**2,9**

Annex 9: HUMAN BITING RATE OF *ANOPHELES GAMBIAE*, S.L. IN SPRAYED VILLAGES AND THEIR CONTROLS

Districts		Sprayed villages						Internal control						External control					
		Jul.	Aug	Sept.	Oct.	Nov.	Total	Jul.	Aug	Sept.	Oct.	Nov.	Total	Jul.	Aug	Sept.	Oct.	Nov.	Total
Koungheul	HN	-	24	24	24	24	96	-	24	24	24	24	96	24	24	24	24	24	120
	Number	-	13	30	31	15	89	-	7	4	14	9	34	11	17	17	46	42	133
	HBR	-	**0,54**	**1,25**	**1,29**	**0,63**	**0,93**	-	**0,29**	**0,17**	**0,58**	**0,38**	**0,35**	**0,46**	**0,71**	**0,71**	**1,92**	**1,75**	**1,11**
Koumpentoum	HN	-	24	24	24	24	96	-	24	24	24	24	96	24	24	24	24	24	120
	Number	-	0	3	27	6	36	-	2	2	6	2	12	11	46	136	163	65	421
	HBR	-	**0**	**0,13**	**1,13**	**0,25**	**0,38**	-	**0,08**	**0,08**	**0,25**	**0,08**	**0,13**	**0,46**	**1,92**	**5,67**	**6,8**	**2,71**	**3,51**
Malem Hoddar	HN	-	24	24	24	24	96	-	24	24	24	24	96	24	24	24	24	24	120
	Number	-	1	3	14	17	35	-	8	0	9	36	53	13	12	3	26	33	87
	HBR	-	**0,04**	**0,13**	**0,58**	**0,71**	**0,36**	-	**0,33**	**0**	**0,38**	**1,5**	**0,55**	**0,58**	**0,50**	**0,13**	**1,08**	**1,38**	**0,73**

Annex 10: HUMAN BITING RATE OF *ANOPHELES GAMBIAE*, S.L. AND *ANOPHELES FUNESTUS* IN SPRAYED VILLAGES AND THEIR CONTROL

Species	Method		Sprayed villages						Internal control						External control					
			Jul.	Aug	Sept.	Oct.	Nov.	Total	Jul.	Aug	Sept.	Oct.	Nov.	Total	Jul.	Aug	Sept.	Oct.	Nov.	Total
Anopheles gambiae, s.l.	HLC	HN	-	20	24	24	24	92	-	20	20	20	20	80	16	16	16	16	16	80
		Number	-	8	9	79	13	109	-	15	31	80	30	156	35	27	12	50	18	142
		HBR	-	**0,4**	**0,38**	**3,29**	**0,54**	**1,18**	-	**0,75**	**1,55**	**4**	**1,5**	**1,95**	**2,19**	**1,69**	**0,75**	**3,13**	**1,13**	**1,77**
	CDC LT	HN	-	12	-	-	-	12	-	8	8	8	8	32	16	16	16	16	16	80
		Number	-	3	-	-	-	3	-	4	30	13	7	54	4	2	12	6	1	25
		HBR	-	**0,25**	**-**	**-**	**-**	**0,25**	-	**0,5**	**3,75**	**1,63**	**0,88**	**1,69**	**0,25**	**0,13**	**0,75**	**0,38**	**0,06**	**0,31**
Anopheles funestus	HLC	HN	-	20	24	24	24	92	-	20	20	20	20	80	16	16	16	16	16	80
		Number	-	14	37	165	118	334	-	11	34	51	106	202	163	61	59	46	87	416
		HBR	-	**0,7**	**1,54**	**6,88**	**4,92**	**3,63**	-	**0,55**	**1,70**	**2,55**	**5,30**	**2,53**	**10,2**	**3,81**	**3,69**	**2,88**	**5,44**	**5,2**
	CDC LT	HN	-	12	-	-	-	12	-	8	8	8	8	32	16	16	16	16	16	80
		Number	-	4	-	-	-	4	-	2	32	23	67	124	33	21	10	9	20	93
		HBR	-	**0,33**	**-**	**-**	**-**	**0,33**	-	**0,25**	**4**	**2,88**	**8,38**	**3,88**	**2,06**	**1,31**	**0,63**	**0,56**	**1,25**	**1,16**

Annex 11: INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE, S.L.* BY PSC IN SPRAYED VILLAGES AND THEIR CONTROL IN KOUNGHEUL, KOUMPENTOUM AND MALEM HODAR

Districts		Sprayed villages						Internal control						External control					
		Jul.	Aug	Sept.	Oct.	Nov.	Total	Jul.	Aug	Sept.	Oct.	Nov.	Total	Jul.	Aug	Sept.	Oct.	Nov.	Total
Koungheul	NP	-	20	20	20	20	80	-	20	20	20	20	80	20	20	20	20	20	100
	Number	-	8	3	32	43	86	-	14	5	26	29	74	71	60	58	93	109	391
	IRD	-	**0,40**	**0,15**	**1,60**	**2,15**	**1,08**	-	**0,70**	**0,25**	**1,30**	**1,45**	**0,93**	**3,55**	**3,00**	**2,90**	**4,65**	**5,45**	**3,91**
Koumpentoum	NP	-	20	20	20	20	80	-	20	20	20	20	80	20	20	20	20	20	100
	Number	-	14	11	59	27	111	-	13	6	14	18	51	31	38	64	90	434	657
	IRD	-	**0,70**	**0,55**	**2,95**	**1,35**	**1,39**	-	**0,65**	**0,30**	**0,70**	**0,90**	**0,64**	**1,55**	**1,90**	**3,20**	**4,50**	**21,70**	**6,57**
Malem Hodar	NP	-	20	20	20	20	80	-	20	20	20	20	80	20	20	20	20	20	100
	Number	-	6	34	19	40	99	-	21	6	18	52	97	39	36	18	43	162	298
	IRD	-	**0,30**	**1,70**	**0,95**	**2,0**	**1,24**	-	**1,05**	**0,30**	**0,90**	**2,60**	**1,21**	**1,95**	**1,80**	**0,90**	**2,15**	**8,10**	**2,98**

Annex 12: INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE, S.L.* BY PSC IN SPRAYED VILLAGES AND THEIR CONTROL IN NIORO.

Espèce	Méthode		Sprayed villages						Internal control						External control					
			Jul.	Aug	Sept.	Jul.	Aug	Sept.	Jul.	Aug	Sept.	Jul.	Aug	Sept.	Jul.	Aug	Sept.	Jul.	Aug	Sept.
Anopheles gambiae, s.l.	PSC	NP	-	20	20	20	20	80	-	20	20	20	20	80	20	20	20	20	20	100
		Number	-	42	46	75	64	227	-	138	70	255	119	582	20	95	37	69	16	237
		IRD	-	**2,10**	**2,30**	**3,75**	**3,20**	**2,84**	-	**6,90**	**3,50**	**12,75**	**5,95**	**7,28**	**1,00**	**4,75**	**1,85**	**3,45**	**0,80**	**2,37**
	Proko	NP	-	20	20	20	20	80	-	20	20	20	20	80	20	20	20	20	20	100
		Number	-	-	-	-	-	-	-	1	4	15	12	32	3	10	1	15	4	33
		IRD	-	-	-	-	-	-	-	**0,05**	**0,20**	**0,75**	**0,60**	**0,40**	**0,15**	**0,50**	**0,05**	**0,75**	**0,20**	**3,3**
Anopheles funestus	PSC	NP	-	20	20	20	20	80	-	20	20	20	20	80	20	20	20	20	20	100
		Number	-	9	27	23	71	130	-	22	26	72	154	274	92	146	55	20	42	355
		IRD	-	**0,45**	**1,35**	**1,15**	**3,55**	**1,63**	-	**1,10**	**1,30**	**3,60**	**7,70**	**3,43**	**4,60**	**7,30**	**2,75**	**1,00**	**2,10**	**3,55**
	Proko	NP	-	20	20	20	20	80	-	20	20	20	20	80	20	20	20	20	20	100
		Number	-	-	-	-	-	-	-	1	13	30	59	103	13	17	3	9	6	48
		IRD	-	-	-	-	-	-	-	**0,05**	**0,65**	**1,50**	**2,95**	**1,29**	**0,65**	**0,15**	**0,45**	**0,30**	**0,60**	**0,48**

NB: The method of collecting anopheline populations with prokopack was not used in the sprayed villages of the Nioro district
PSC: Pyrethroid Spray Catches; Proko: prokopack

Annex 13: REPRODUCTIVE STATUS OF *ANOPHELES GAMBIAE, S.L.* FEMALE COLLECTED BY PSC

District	Statut	August				September				October				November				Total			
		Go	Gr	SGr	AJ	Go	Gr	SGr	AJ	Go	Gr	SGr	AJ	Go	Gr	SGr	AJ	Go	Gr	SGr	AJ
Koungheul	Sprayed	14	0	8	0	4	0	4	0	43	6	9	0	31	12	25	4	**92**	**18**	**46**	**4**
Koumpentoum	Sprayed	10	13	4	0	12	0	3	2	43	28	0	2	16	17	8	4	**81**	**58**	**15**	**8**
Malem Hoddar	Sprayed	13	8	2	4	32	2	6	0	27	1	8	1	58	10	13	11	**130**	**21**	**29**	**16**
Nioro	Sprayed	84	38	44	14	80	18	12	6	225	57	40	8	118	13	44	8	**507**	**126**	**140**	**36**
Kaffrine (Kgl)	Unsprayed	39	15	2	4	31	20	6	1	53	20	20	0	61	22	24	2	**184**	**77**	**52**	**7**
Tambacounda	Unsprayed	20	17	1	0	38	19	6	1	72	18	0	0	190	146	77	21	**320**	**200**	**84**	**22**
Kaffrine (Mal)	Unsprayed	18	3	14	1	9	1	6	2	25	11	6	1	85	36	35	6	**137**	**51**	**61**	**10**
Ndoffane	Unsprayed	50	4	35	6	19	6	10	2	44	3	21	1	7	9	0	0	**120**	**13**	**75**	**9**
Niayes	Unsprayed	10	31	4	1	-	-	-	-	11	36	22	4	-	-	-	-	**21**	**67**	**26**	**5**
Velingara	Unsprayed	35	18	0	3	-	-	-	-	8	8	2	0	-	-	-	-	**43**	**26**	**2**	**3**
Kédougou	Unsprayed	35	13	1	7	55	6	0	6	-	-	-	-	7	2	0	1	**97**	**21**	**1**	**14**

Annex 14: PARITY RATE (% PAROUS FEMALES) OF *ANOPHELES GAMBIAE*, S.L. COLLECTED BY HLC IN IRS DISTRICT

Month	Koungheul			Koumpentoum			Malem Hodar			Nioro		
	TC	TD	PR	TC	TD	PR	TC	TD	PR	TC	TD	PR
August	20	10	70% (7/10)	2	1	100% (1/1)	9	7	57,1% (4/7)	23	19	63,2% (12/19)
September	34	32	53,1% (17/32)	5	4	50% (2/4)	3	3	100% (3/3)	40	29	55,2% (16/29)
October	45	35	51,4% (18/35)	33	30	86,7% (26/30)	23	22	45,5% (10/22)	159	112	66,1% (74/112)
November	24	15	66,7% (10/15)	8	7	42,9% (3/7)	53	46	76,1% (35/46)	43	16	81,3% (13/16)
Total	**123**	**92**	**56,5% (52/92)**	**48**	**39**	**82,1% (32/39)**	**88**	**78**	**62,8% (49/78)**	**265**	**176**	**65,3% (115/176)**

TC: Total Collected; TD: Total Dissected; PR: Parity Rate

Annex 15: PARITY RATE IN IRS DISTRICTS AND THEIR CONTROLS

Districts	Villages	July			August			September			October			November			Total		
		TC	TD	PR	TC	TD	PR	TC	TD	PR	TC	TD	PR	TC	TD	PR	TC	TD	PR
Koungheul	Sprayed	-	-	-	13	6	83,3% (5/6)	30	28	50% (14/28	31	28	39,3% (11/28)	15	12	75% (9/12)	**89**	**74**	**52,7% (39/74)**
	Internal Control	-	-	-	7	4	50% (2/4)	4	4	75% (3/4)	14	7	100% (7/7)	9	3	33,3% (1/3)	**34**	**18**	**72,2% (13/18)**
	External control	11	5	40% (2/5)	17	9	88,9% (8/9)	17	10	70% (7/10)	46	32	87,5% (28/32)	42	36	83,3% (30/36)	**133**	**92**	**81,5% (75/92)**
Koumpentoum	Sprayed	-	-	-	0	0	0%	3	3	66,7% (2/3)	27	24	83,3% (20/24)	6	6	50% (3/6)	**36**	**30**	**83,3% (25/30)**
	Internal Control	-	-	-	2	1	100%	2	1	0%	6	6	100%	2	1	0%	**12**	**9**	**77,8% (7/9)**
	External control	11	3	33,33% (1/3)	46	31	80,64% (25/31)	136	122	63,11% (77/122)	163	129	93,02% (120/129)	65	49	87,75% (43/49)	**421**	**334**	**79,64% (266/334)**
Malem Hodar	Sprayed	-	-	-	1	1	0%	3	3	100%	14	13	23,1% (3/13)	17	15	73,33% (11/15)	**35**	**32**	**43,75% (14/32)**
	Internal Control	-	-	-	8	6	66,7% (4/6)	0	0	0%	9	9	77,8% (7/9)	36	31	77,42 (24/31)	**53**	**46**	**76,09 (35/46)**
	External control	13	7	14,3% (1/7)	12	10	40% (4/10)	3	3	33,3% (1/3)	26	20	65% (13/20)	33	28	89,3% (25/28)	**87**	**68**	**64,71% (44/68)**

TC: Total Collected; TD: Total Dissected; PR: Parity Rate

Annex 16: PARITY RATE OF *ANOPHELES GAMBIAE*, S.L. AND *ANOPHELES FUNESTUS* COLLECTED ON HLC IN NIORO AND ITS CONTROL (NDOFFANE)

Species	Villages	July			August			September			October			November			Total		
		TC	TD	TP	TC	TD	TP	TC	TD	TP	TC	TD	TP	TC	TD	TP	TC	TD	TP
Anopheles gambiae, s.l.	Sprayed	-	-	-	8	6	50% (3/6)	9	7	85,71% (6/7)	79	57	64,91% (37/57)	13	4	75% (3/4)	**109**	**74**	**66,22% (49/74)**
	Internal Control	-	-	-	15	13	69,23% (9/13)	31	22	45,45% (10/22)	80	55	67,27% (37/55)	30	12	83,33% (10/12)	**156**	**102**	**64,71% (66/102)**
	External control	35	22	18,18% (4/22)	27	13	76,92% (10/13)	12	11	63,64% (7/11)	50	39	71,79% (28/39)	18	9	66,67% (6/9)	**142**	**94**	**66,2% (94/142)**
Anopheles funestus	Sprayed	-	-	-	14	10	60% (6/10)	37	30	36,67% (11/30)	165	116	32,76% (38/116)	118	56	69,64% (39/56)	**334**	**212**	**44,34% (94/212)**
	Internal Control	-	-	-	11	5	60% (3/5)	34	26	69,23% (18/26)	51	33	69,70% (23/33)	106	48	66,67% (32/48)	**202**	**112**	**67,86% (76/112)**
	External control	163	77	54,55% (42/77)	61	39	94,87% (37/39)	59	55	50,91% (28/55)	46	38	86,84% (33/38)	87	55	83,64% (46/55)	**416**	**264**	**70,45% (186/264)**

Annex 17a: SPECIFIC COMPOSITION OF ANOPHELINE FAUNA ACCORDING TO THE SAMPLING METHOD AND PARITY RATES IN UNSPRAYED DISTRICTS DURING THE RAINY SEASON

Districts	Species	HLC	CDC LT	PSC	Prokopack#	Total collected	Parity*		
							Collected	Dissected	Parous
Kedougou	*An. gambiae* s.l.	2264	233	133	22	2652	2497	886	63% (559/886)
	An. funestus	4	12	2	0	18	2497		
	An. pharoensis	0	1	0	0	1	-	-	-
	An. nili	2	2	0	1	6	-	-	-
Ndoffane	*An. gambiae* s.l.	142	25	237	33	437	167	98	60,2% (59/98)
	An. funestus	416	93	355	48	912	-	-	-
	An. pharoensis	1	3	0	0	4	-	-	-
Niayes	*An. gambiae* s.l.	3	-	119	1	123	3	2	66,6% (2/3)
	An. funestus	0	-	14	0	14	-	-	-
Richard-Toll	*An. gambiae* s.l.	14	1	352	105	472	15	9	44,44% (4/9)
	An. funestus	0	0	3	1	4	-	-	-
	An. pharoensis	116	92	39	14	261	208	105	18,09% (19/105)
	An coustani	0	2	0	0	2	-	-	-
	An rufipes	0	0	10	5	15	-	-	-

* Parturity was evaluated only for *An gambiae, s.l.*

The method of collecting anopheline populations in the prokopack was used only in August in the Niayes area.

Annex 17b: SPECIFIC COMPOSITION OF ANOPHELINE FAUNA ACCORDING TO THE SAMPLING METHOD AND PARITY RATES IN UNSPRAYED DISTRICTS DURING THE RAINY SEASON

Districts	Species	HLC	CDC LT	PSC	Prokopack#	Total collected	Parity*		
							Collected	Disséqués	Pares
Velingara	*An. gambiae* s.l.	522	-	74	-	596	522	391	66,50% (260/391)
	An. funestus	0	-	10	-	10	-	-	-
	An. pharoensis	2	-	0	-	2	-	-	-
	An. nili	3	-	-	-	3	-	-	-
Kaffrine	*An. gambiae* s.l.	138	-	478	-	616	138	104	69,23% (72/104)
	An. funestus	0	-	1	-	1	-	-	-
	An. pharoensis	5	-	0	-	5	-	-	-
	An. rufipes	0	-	1		1	-	-	-
Tambacounda	*An. gambiae* s.l.	421	-	657	-	1078	421	334	79,64% (266/334)
	An. pharoensis	7	-	0	-	7	-	-	-

Annex 18: HUMAN BITING RATE AND INDOOR RESTING DENSITY OF*ANOPHELES GAMBIAE* S.L. IN UNSPRAYED DISTRICTS DURING RAINY SEASON

Districts		HLC (HBR)																		PSC (IRD)*					
		Indoor						Outdoor						Total											
		J	A	S	O	N	T	J	A	S	O	N	T	J	A	S	O	N	T	J	A	S	O	N	T
Kedougou	HN/R	8	-	8	-	8	24	8	-	8	-	8	24	16	-	16	-	16	48	20	-	20	-	20	60
	Number	484	-	703	-	19	1206	426	-	615	-	17	1058	910	-	1318	-	36	2264	56	-	69	-	10	135
	HBR/IRD	60,5	-	87,9	-	2,38	50,3	53,3	-	76,9	-	2,13	44,1	56,9	-	82,37	-	2,25	47,17	2,8	-	3,45	-	0,5	2,25
Ndoffane	HN/R	8	8	8	8	8	40	8	8	8	8	8	40	16	16	16	16	16	80	20	20	20	20	20	100
	Number	13	7	8	25	11	64	22	20	4	25	7	78	35	27	12	50	18	142	20	95	37	69	19	237
	HBR/IRD	1,63	0,88	1	3,13	1,38	1,16	2,75	2,5	0,5	3,13	0,88	1,95	2,19	1,69	0,75	3,12	1,12	1,78	1	4,75	1,85	3,45	0,95	2,37
Niayes	HN/R	-	12	-	12	-	24	-	12	-	12	-	24	-	24	-	24	-	48	-	50	-	50	-	100
	Number	-	0	-	1	-	1	-	0	-	2	-	2	-	0	-	3	-	3	-	46	-	73	-	119
	HBR/IRD	-	0	-	0,08	-	0,04	-	0	-	0,17	-	0,08	-	0	-	0,12	-	0,06	-	0,92	-	1,46	-	1,19
Richard-Toll	HN/R	-	-	8	-	-	8	-	-	8	-	-	8	-	-	16	-	-	16	-	-	100	-	-	100
	Number	-	-	7	-	-	7	-	-	7	-	-	7	-	-	14	-	-	14	-	-	352	-	-	352
	HBR/IRD	-	-	0,88	-	-	0,88	-	-	0,88	-	-	0,88	-	-	0,87	-	-	0,87	-	-	3,52	-	-	3,52
Velingara	HN/R	-	12	-	12	-	24	-	12	-	12	-	24	-	24	-	24	-	48	-	20	-	20	-	40
	Number	-	165	-	68	-	233	-	202	-	87	-	289	-	367	-	155	-	522	-	56	-	18	-	74
	HBR/IRD	-	13,8	-	5,67	-	9,71	-	16,8	-	7,25	-	12	-	15,29	-	6,45	-	10,88	-	2,8	-	0,9	-	1,85
Kaffrine	HN/R	24	24	24	24	24	120	24	24	24	24	24	120	48	48	48	48	48	240	40	40	40	40	40	200
	Number	10	16	1	34	22	83	14	7	4	17	13	55	24	23	5	51	35	138	110	53	32	90	222	507
	HBR/IRD	0,42	0,67	0,04	1,42	0,92	0,69	0,58	0,29	0,17	0,71	0,54	0,46	0,5	0,48	0,10	1,06	0,73	0,57	2,75	1,32	0,8	2,25	5,55	2,53
Tambacounda	HN/R	12	12	12	12	12	60	12	12	12	12	12	60	24	24	24	24	24	120	20	20	20	20	20	100
	Number	5	15	55	67	21	163	6	31	81	96	44	258	11	46	136	163	65	421	31	38	64	90	434	657
	HBR/IRD	0,42	1,25	4,58	5,58	1,75	2,72	0,5	2,58	6,75	8	3,67	4,3	0,46	1,91	5,67	6,79	2,7	3,5	1,55	1,9	3,2	4,5	21,7	6,57

Annex 19: COMPARISON OF THE PERFORMANCE OF ADULT MOSQUITO COLLECTION METHODS OF ANOPHELES *GAMBIAE*, S.L. IN SOME DISTRICTS

		Feeding collect										Resting collect									
Districts		**HLC**					**CDC LT**					**PSC**					**Prokopack**				
		A	S	O	N	T	A	S	O	N	T	A	S	O	N	T	A	S	O	N	T
Kedougou	HN	-	16	-	16	32	-	16	-	16	32	-	20	-	20	40	-	20	-	20	40
	Number	-	1318	-	36	1354	-	88	-	9	97	-	67	-	10	77	-	12	-	0	12
	Density	**-**	**82,37**	**-**	**2,25**	**42,31**	**-**	**5,5**	**-**	**0,56**	**3,03**	**-**	**3,35**	**-**	**0,5**	**1,92**	**-**	**0,6**	**-**	**0**	**0,3**
Ndoffane	HN	16	16	16	16	64	16	16	16	16	64	20	20	20	20	80	20	20	20	20	80
	Number	27	12	50	18	107	2	12	6	1	21	95	37	69	16	217	10	1	15	4	30
	Density	**1,7**	**0,8**	**3,1**	**1,1**	**1,7**	**0,1**	**0,8**	**0,4**	**0,1**	**0,3**	**4,8**	**1,9**	**3,5**	**0,8**	**2,7**	**0,5**	**0,1**	**0,8**	**0,2**	**0,4**
Niayes	HN	24	-	24	-	48	-	-	-	-	-	50	-	50	-	100	50	-	50	-	100
	Number	0	-	3	-	3	-	-	-	-	-	46	-	73	-	119	1	-	0	-	1
	Density	**0,04**	**-**	**0,13**	**-**	**0,08**	**-**	**-**	**-**	**-**	**-**	**0,9**	**-**	**1,46**	**-**	**1,18**	**0,02**	**-**	**0**	**-**	**0,01**
Richard-Toll	HN	-	16	-	-	16	-	16	-	-	16	-	100	-	-	100	-	100	-	-	100
	Number	-	14	-	-	14	-	1	-	-	1	-	352	-	-	352	-	105	-	-	105
	Density	**-**	**0,87**	**-**	**-**	**0,87**	**-**	**0,06**	**-**	**-**	**0,06**	**-**	**3,52**	**-**	**-**	**3,52**	**-**	**1,05**	**-**	**-**	**1,05**
Nioro	HN	40	52	44	44	180	20	8	8	8	44	40	40	40	40	160	10	10	10	10	40
	Number	23	40	159	43	265	7	30	13	7	57	180	116	330	183	809	1	4	15	12	32
	Density	**0,6**	**0,8**	**3,6**	**1**	**1,5**	**0,4**	**3,8**	**1,6**	**0,9**	**1,3**	**9**	**5,8**	**16,5**	**9,15**	**10,1**	**0,1**	**0,4**	**1,5**	**1,2**	**0,8**
Velingara	HN	**24**	**-**	**24**	**-**	**48**	**-**	**-**	**-**	**-**	**-**	**20**	**-**	**20**	**-**	**40**	**-**	**-**	**-**	**-**	**-**
	Number	**367**	**-**	**155**	**-**	**522**	**-**	**-**	**-**	**-**	**-**	**56**	**-**	**18**	**-**	**74**	**-**	**-**	**-**	**-**	**-**
	Density	**15,29**	**-**	**6,46**	**-**	**10,88**	**-**	**-**	**-**	**-**	**-**	**2,80**	**-**	**0,90**	**-**	**1,85**	**-**	**-**	**-**	**-**	**-**

Annex 20: NUMBER AND MORTALITY RATE OF FEMALE ANOPHELES GAMBIAE S. L. 24 HOURS AFTER 1 HOUR EXPOSURE TO INSECTICIDES TESTED

Districts	Deltamethrin 0,05%			Lambdacyhalothin 0,05%			Permethrin 0,75%			DDT 4%			Pirimiphos-methyl 0.25%			Bendiocarb 0,1%		
	No tested	Death 24h	%	No tested	Death 24h	%	No tested	Death 24h	%	No tested	Death 24h	%	No tested	Death 24h	%	No tested	Death 24h	%
Richard Toll	119	95	80	120	57	48*	123	89	72	125	19	15	107	107	100	107	107	100
Niayes	102	78	76,5	114	75	65,8	101	97	96	122	45	31,4*	102	102	100	100	96	96
Pikine																		
Rufisque																		
Campus UCAD	100	39	36*	109	50	46	101	28	25*	104	27	23	100	100	100	122	97	79,5
Colobane (Dkr)	102	100	98	100	95	95	103	75	73	-	-	-	-	-	-	-	-	-
Niakhar	106	105	99,1	104	103	99	103	85	82,5	107	57	53,3	105	105	100	110	110	100
Guinguinéo	104	78	75	103	88	84,6*	108	80	74,1	109	34	31,2	114	114	100	103	103	100
Diourbel	108	97	89,2*	112	91	80,1*	107	91	84,1*	104	57	54,8	-	-	-	108	102	94,4
Nioro	11	72	62*	133	99	72,4*	106	76	69*	114	93	82	142	142	100	123	123	100
Ndoffane	110	80	71,2*	134	67	50	113	81	70*	106	71	67	124	124	100	105	105	100
Kaffrine#	101	78	77	124	88	70*	101	60	59	121	91	75	100	100	100	123	123	100
Malem Hodar	107	96	89,7	107	104	97,2	123	105	85,4	111	83	74,8	102	102	100	105	105	100
Koungheul	101	83	82	107	79	73,8	102	100	98*	138	126	91,3	125	125	100*	107	107	100*
Koumpentoum	100	94	94	103	68	62*	101	93	91*	103	84	81,6	103	103	100	105	103	98,1
Tambacounda	211	129	61,1	239	170	71,1*	234	173	73,9	209	89	42,6	209	208	99,5*	215	213	99,1*
Vélingara	121	103	83,4*	128	74	54,2*	123	103	81,8*	107	83	74,6*	130	130	100*	105	105	100
Kédougou	120	76	61*	116	49	36*	124	57	43*	125	16	8*	123	123	100*	113	105	92,5